The Grid Connected Roof Top Solar Project in Army Institute of Technology; a Case Study

Ms Mridula Chandola*, Dr Seema Tiwari, Mr Rushikesh Patil

Army Institute of Technology, Dighi, Pune

Abstract: Educational Institutions are often under pressure for cost cutting. Electricity charges, especially in a residential institution, is one of the biggest drain on finances. In this case study, we would like to discuss the grid connected roof top solar project in Army Institute of Technology (AIT), Dighi, Pune. This 350 kW system has been installed without any cost to AIT, on Build-Operate-Transfer (BOT) model, for 25 years at the rate of Rs 6/- per electricity unit. The power generated by the system is approximately 1000 to 1200 electricity units per day as against a requirement of about 1800 to 2000 electricity units per day. Net Metering Policy implemented by Maharashtra Government enables AIT to send excess electricity generated during day time back to the grid. This excess power given to the grid is credited back during night time. A new Net Meter has been installed in AIT that provides daily status of the power import/export. This has resulted in Cost Savings of nearly Rs 1,50,000/- per month which comes close to Rs 18,00,000/- per annum.

Keywords: AIT, Build-Operate-Transfer, cost cutting, grid, roof top, solar

1. Introduction

Army Institute of Technology, Pune (AIT) which is located at Dighi on Alandi road, in Pune, is one of the reputed undergraduate engineering college. It is affiliated to the Savitribai Phule Pune University (SPPU). AIT is established only for the wards of Army Personnel, by a special permission from the Supreme Court of India. AIT functions under the patronage of the Army Welfare Education Society (AWES). As AIT is intended to be a residential college, with more than 1300 students staying on its campus, it attempts to be self-contained. The most important building and by far the largest in AIT, is the Academic Block, which accommodates most of the lecture halls and laboratories, some of which are airconditioned, offices for the administration and an auditorium. Since AIT is a residential college, it has separate hostels for girls and boys, as well as staff quarters, on its campus. There are various shops for common household products, messes and cafeterias, along with an ATM of the HDFC Bank. Sports are encouraged in AIT and the campus has well maintained basketball court, a cricket ground, a volleyball court, a tennis court, a football ground, a badminton court, separate gym for girls and boys, a croquet lawn and two squash courts. AIT also has some popular indoor sports like chess, pocket billiards and table tennis. AIT library and the reading rooms are open to all staff and students for 18 hours a day.

As can be deduced from above, electricity is consumed to a great extent in day to day functioning of the institute.

In teaching and learning also there has been a major shift towards usage of ICT tools. Increased usage of technology both in teaching and learning and in everyday life has resulted in increased dependence on electricity.

Further, the electricity price has been rising steadily. This had become a substantial burden on the institute's resources, especially since AIT is a residential, self-sufficient institution.

The institute brainstormed for a strategy with a goal to move towards a cheaper and more sustainable energy source, possibly with lesser carbon footprint.

The solution to the above mentioned problem was found in the Grid Connected Roof Top Solar Power Generator (Nwaigwe et al 2019; Tobnaghi 2016; Chang and Tao 2013; Khyani, and Vajpai, 2014; Meena et al, 2014). A typical diagram of rooftop solar system is shown in Fig 1.

Solar energy is the least expensive amongst all sources of renewable energy and it is available in abundance and free of cost in most of the regions in the world (Kabir E., Kumar P., Kumar S., Adelodun A. A., Kim K., 2016; Kannan and Vakeesan 2016; Wiginton et al 2010).

As per Ministry of New and Renewable Energy, Government of India, a road map for generation of solar power till 2022 is 1,00,000MW. Out of this 40,000MW is dedicated for solar rooftop projects only. (Source: https://mnre.gov.in/img/documents/uploads/cf28af553bf04afe87a972e4aba0987a.pdf)

Corresponding Author
*Applied Sciences and General Engineering Department, Army Institute of Technology, Dighi, Alandi Road, Pune-411015, India
*mchandola@aitpune.edu.in

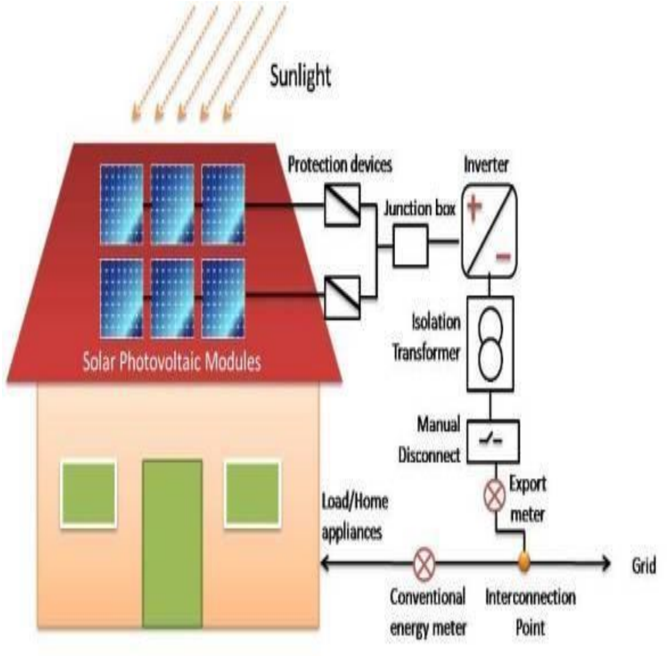

Fig1: A typical rooftop solar system (Source: www.greencleanguide.com).

A rooftop photovoltaic system uses one or more than one photovoltaic panel which are installed on rooftops of commercial or residential buildings and they convert natural sunlight into electricity (Mohanta, et al 2015).

Two types of roof top Solar Photo Voltaic (SPV) systems are used: stand-alone system and grid connected system (R. Ghule et al 2008).

- Stand-alone roof top solar photovoltaic systems: They do not have a connection to an electricity grid. The excess electricity generated is stored in the batteries, which is used during non- sunlight hours.
- Grid-connected solar photo voltaic systems**:** They are connected to the p*ublic electricity grid using a suitable inverter. (Kumar 2014). This assembly involves a Net meter that maintains a record of the electricity units transferred to the grid.

The roof top solar power plant at AIT is grid connected solar photo voltaic system. In this system two types of metering configurations are possible:

- Gross metered rooftop solar panel, shown in Fig 2.
- Net metered rooftop solar panel, depicted in Fig 3 (Kappagantua 2015).

The assembly in AIT consists of the Net metered rooftop solar panel system.

Presently, a 350 kW Grid Connected Roof Top Solar system exists in AIT, which has been installed without any cost, on Build-Operate-Transfer (BOT) model, for 25 years, at a flat fixed rate of Rs 6/- per electricity unit.

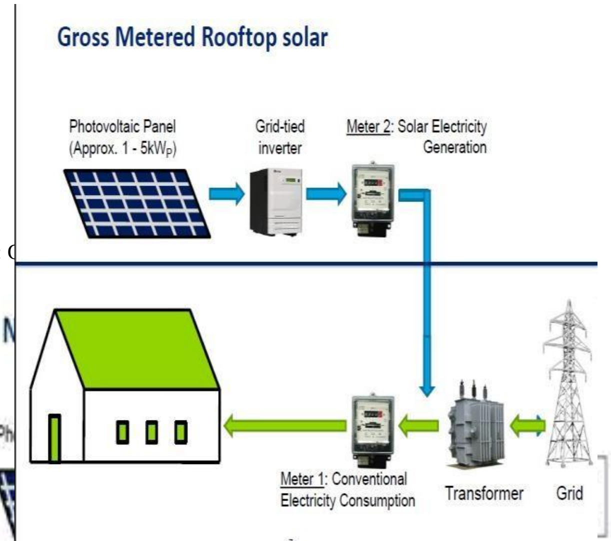

Fig2: (

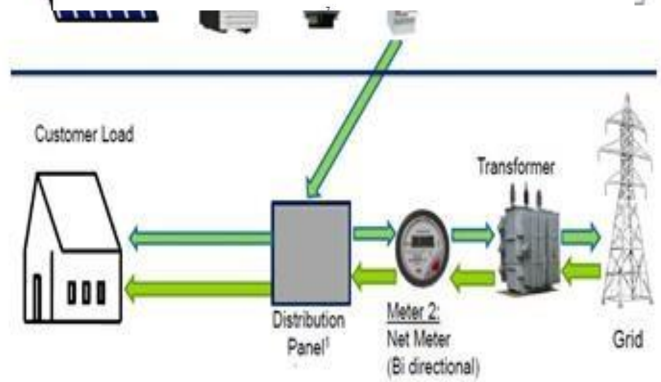

Fig3: Net metered arrangement of rooftop solar panel.

Fig2 and Fig3 (Meena et al 2014), show the comparison between the Gross metered and the Net metered, rooftop solar panel.

There are two sections in the paper. The first section gives details of the technical specification of our case study while the second section provides details of the economic analysis of the system.

2. Technical Specifications

2.1 Project goal:

- The primary goal of the project was to reduce operating costs while ensuring that the carbon emission footprint for generating that power was simultaneously reduced by opting for solar power.
- An auxiliary goal of the project was to facilitate and encourage the students towards working on innovation in Green Technologies by providing them access to live solar project environment.

2.2 Project details:

Fig 4(a): Top view of installed solar panel.

A basic requirement for the efficient working of the solar panels mandates that no shadows should fall on the panels. This is because:

- The part of the panel on which a shadow falls cannot produce electricity, reducing the output.
- Besides, the section of the panel in shade gets converted from a conductor to a resistor, and starts heating up. This portion of the solar panel that is in shade will eventually burn out and would result in the entire panel having to be replaced.

Therefore, for proper working of the Grid Connected Roof Top Solar plant it is critical to ensure that no shadow falls on the panels, throughout the year. Shadows that fall on the panel could be from neighboring structures or even trees. In addition, one row of panel may cast a shadow on the row behind.

The building with the largest roof top in AIT is the Academic Block. Since there are no other tall structures or trees in close proximity to the Academic block, it remains shade-free throughout the year. Hence an initial installation of 225 kW Roof Top Grid Connected System was done, in August 2014, on top of the academic block. The solar panels are south facing and kept inclined at an angle of 25-30 degrees with respect to the horizontal, in order to maximize the generation of electricity. The system was established without any cost to AIT on BOT (Build-Operate-Transfer) basis for a period of 25 years at a fixed flat rate of Rs- 6/- per electricity unit to the institution.

As the initial results of the installation were highly satisfactory, the above-mentioned system was augmented with an additional capacity of 125 kW Roof Top Grid Connected System in the year 2017.

The total installed capacity of Solar Roof Top Grid Connected System in AIT is currently 350 kW. The project contractor is

Fig 4(b): Side view of installed solar panels.
Pictures (Fig 4(a) and (b)) show The Grid Connected Roof Top Solar Project at AIT.

M/s Aditya Green Energy Pvt Ltd (EPC) (Latur) and the Financer is M/s Keerti Enterprise, Latur (M.S.).

2.3 Key Features of the Project:

- Year of Establishment – 2014.
- 350 kW Solar Electric System.
- Generates approximately 1200 electricity units per day.
- About 50% electricity demand of AIT is fulfilled by this system.
- 25 years operations and maintenance plan.
- Roof top Area is 35000 sq. ft.
- State of the art, highly efficient panels by ADITYA SERIES POLY WS-290 to WS- 325 (72 Cells - 6") and 280Wp from Waaree Energies Limited, more than 800 in number. (Source: https://www.waaree.com/)
- Inverter: Make - SMA; Type - SMC 11000 TLRP.
- Solar Energy System synchronized with the Generators using a synchronization panel.
- Net-Metered Project exports excess generation to the local utility grid that is controlled by Maharashtra State Electricity Distribution Company Limited (MSEDCL).
- For measuring the export as well as the import of electricity units a single bi-directional meter is used.

- Savings in Carbon Dioxide emissions - approximately 1200 kg per day.
- Cleaning of installed panels thrice a month along with yearly maintenance costs comes to approximately Rs 30,000/- only.

2.4 Safety Features:

As a part of the Solar Photo Voltaic system, following safety measures have been installed:

- Certified Inverter controlled relays which can trip on grid failure and thus inhibit any solar power injection to Grid, when there is no power in Grid. This is to protect any person/technician working on the grid for maintenance or repair, from getting a shock or being electrocuted. This prevention of bidirectional flow of electricity also prevents damage to electrical appliances at the institution.
- Solar Circuit is separately earthed.
- One additional relay (sensing phase angle shift) is installed, which is important as a second rung of safety. It is positioned between interconnection point and the bi-directional meter.
- Filtering feature as a harmonics suppression in the inverter ensures that there is accurate measurement of energy as well as safety of the local network.

3. Economic Analysis

The Table gives the details of power consumption, generation of solar power, excess power sold to the grid and the savings. The institute has a fairly variable electricity consumption requirement. The requirement can vary from 24,000 electricity units per month to 65,000 electricity units per month. This depends on the month in the academic year and the presence of students in the hostels. The solar grid produces about 32,000 to 50,000 electricity units per month depending on the weather conditions prevalent during that month. The savings are twofold:

- The generated solar power is bought at a flat fixed rate of Rs 6/- per electricity unit. This constitutes an appreciable saving from the rate charged by MSEDCL which is dependent on the consumption in that particular month and is about Rs 10/- per electricity unit. Furthermore, the rates charged by MSEDCL have been increasing gradually, while solar power rate will remain constant for the entire duration of the project i.e., 25 years.
- Extra power generated during the day is fed back or exported into the grid, which results in savings for the institute, though a fixed minimum amount per month which comes to approximately Rs 90,000/- with taxes, always has to be paid to MSEDCL.

The MSEDCL bill includes demand charges, wheeling charges (@0.57 Rs/unit), energy charges, EOD Tariff, Electricity duty, tax on sale (@19.04 ps/unit) etc, on the actual electricity units consumed. Hence the savings on these auxiliary charges that are applicable on the actual electricity units consumed also becomes appreciable.

In the table, column under the heading Savings, is calculated by taking the saving rate as the difference between the per unit rate charged by MSEDCL which is at present Rs 9.48 per electricity unit and the rate paid for the solar units which is Rs 6 per electricity unit. This comes to Rs 3.48 per electricity unit, as savings. Besides this, as mentioned above savings are also earned on the taxes and the allied charges levied on the base cost.

For the duration from Mar’20 to Feb’21, due to COVID pandemic induced lockdown, the hostels were empty and the classrooms and laboratories were also not being utilised. Since AIT is primarily a residential institution, the savings from exporting the extra power to the grid are considerable. In fact, as seen in the table, for the months of April’20 and May’20 when a strict lockdown was imposed nationwide, the savings are more than 100%. In spite of the net export of electricity units to MSEDCL, the institute still had to pay a basic amount to MSEDCL as explained above.

On considering the extra charges and taxes levied by the government the actual rate charged by MSEDCL comes out to be much more than the stated Rs 9.48 per electricity unit. The rate paid to the vendor for the solar power which is fixed at Rs 6 per electricity unit generated and has no other hidden costs, results in much more actual savings for the institute as shown in the table.

Table presents the details of power consumption, generation of solar power, excess power sold to the grid and the savings

MONTH	MSEDCL Electricity		Solar Energy							
	MSEDCL Bill Units (Nos)	Actual MSEDCL Bill Amount Paid (Rs)	Solar Unit Generated (Nos)	Solar Bill Amount paid (Rs) @ Rs 6/unit	Export Solar Units (Nos)	Total Units Consumed (MSEDCL + Solar) (Nos)	Actual Total Bill paid (MSEDCL + Solar) (Rs)	Saving @ 3.48/unit (Excl of Tax & allied charges)	Percentage Saving (%)	Solar Units against Total Units (%)
Jan-19	24918	311961	35165	210990	16067	60083	522951	122374	39	59
Feb-19	30147	377425	42260	253560	14498	72407	630985	147065	39	58
Mar-19	47101	566608	42560	255360	13316	89661	821968	148109	26	47
Apr-19	58197	680500	47705	286230	7203	105902	966730	166013	24	45
May-19	48398	577719	45091	270546	12835	93489	848265	156917	27	48
Jun-19	27681	346553	50300	301800	13067	77981	648353	175044	51	65
Jul-19	65937	744195	35187	211122	3343	101124	955317	122451	16	35
Aug-19	60323	666162	28693	172158	3693	89016	838320	99852	15	32
Sep-19	60547	717792	25648	153888	4379	86195	871680	89255	12	30
Oct-19	59296	710200	32099	192594	8008	91395	902794	111705	16	35
Nov-19	32337	428538	38743	232458	14512	71080	660996	134826	31	55
Dec-19	36994	504528	40358	242148	10840	77352	746676	140446	28	52
Jan-20	32352	458304	34913	209478	14395	67265	667782	121497	27	52
Feb-20	34755	481502	41680	250080	13335	76435	731582	145046	30	55
Avg (Before Lockdown)	**44213**	**540856**	**38600**	**231600**	**10677**	**82813**	**772456**	**134328**	**27**	**48**
Mar-20	12394	2,40,190	41431	248586	25366	53825	488776	144180	60	77
Apr-20	5304	1,41,881	50654	303924	12105	55958	445805	176276	124	91
May-20	4953	1,35,770	49274	295644	11752	54227	431414	171474	126	91
Jun-20	4900	1,94,860	49236	295416	10275	54136	490276	171341	88	91
Jul-20	4646	1,53,910	35749	214494	11217	40395	368404	124407	81	88
Aug-20	4995	1,52,060	34146	204876	13090	39141	356936	118828	78	87
Sep-20	6787	1,55,940	28492	170952	12007	35279	326892	99152	64	81
Oct-20	6740	1,57,380	36711	220266	12582	43451	377646	127754	81	84
Nov-20	6488	1,52,580	35657	213942	11288	42145	366522	124086	81	85
Dec-20	6698	1,54,990	37676	226056	12341	44374	381046	131112	85	85
Jan-21	7038	1,58,820	34881	209286	13013	41919	368106	121386	76	83
Feb-21	6583	1,61,140	36205	217230	16702	42788	378370	125993	78	85
Avg (After Lockdown)	**6460**	**156853**	**39176**	**235056**	**13478**	**45636**	**391909**	**136332**	**85**	**86**

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3.1 Load Consumption:

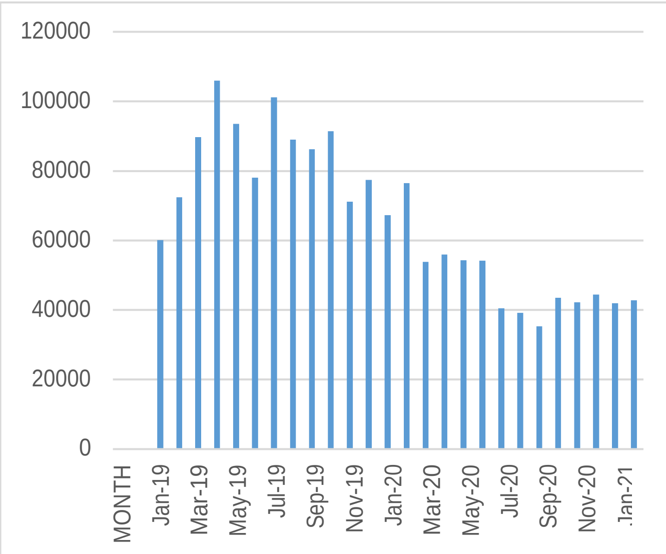

Fig5: Monthly consumption of electricity units over the years

Fig5 shows the number of electricity units consumed per month in routine running of the institute. The consumption peaks during the warmer months of March, April and May and in July, August September and October, as the college is running in full swing with all the students in residence, while it drops during the cooler months or when the students are not on the campus due to various reasons like preparatory leave, vacation, internships etc. On an average 40,000 electricity units are consumed per month. This consumption has reduced since May'20 due to the absence of students on the college premises.

3.2 Solar Energy Generation:

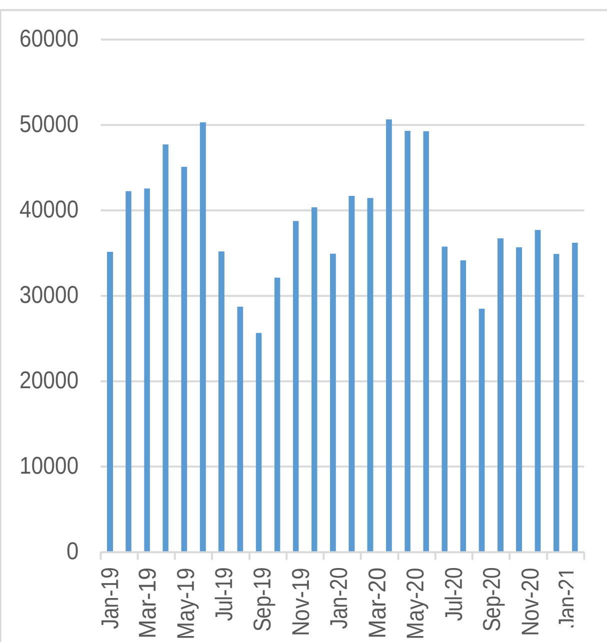

Fig6: Solar units generated per month over the years

As depicted in Fig6 below, power generated through solar panel increases in the hot months with clear skies when compared to the months where the skies are cloudy and it rains. Approximately 39,000 electricity units are generated per month through the roof top solar panel system.

The percentage electricity requirement of the institute generated by the Roof Top Grid Based Solar power plant is shown in Fig7. The Solar power plant furnishes about 50% of the total electricity needs of the institute. Due to lockdown the power usage in the institute has reduced, hence the solar power plant has been able to meet about 80% of the institute's power requirements.

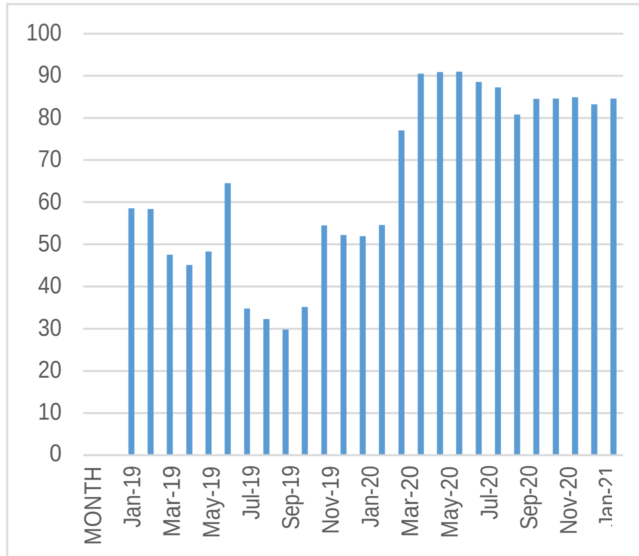

Fig7: % Electricity Requirement Generated by the Solar Plant

3.3 Cost Analysis:

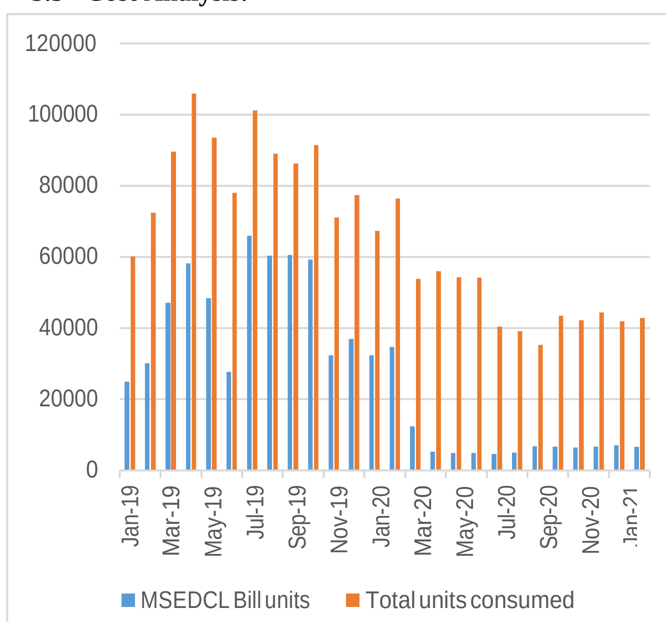

Fig8: MSEDCL Bill Units against the actual consumption

Fig 8 shows the extent to which the savings occur by establishing a Roof Top Grid Connected Solar Power Plant at AIT. The electricity units for which institution is billed are much less than those consumed, which has been further reduced during the lockdown.

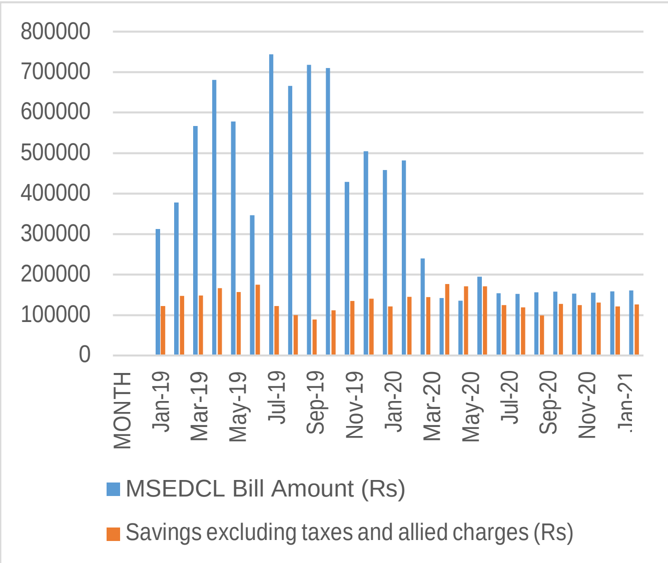

Fig9: Savings (Rs) on MSEDCL bill

The Fig9 displays the comparison between per month MSEDCL bill in rupees with the monthly savings, excluding the taxes and the allied charges, and hence represents the actual saving per month over the period. On an average the institute saves about Rs 1.5 lakh on electricity bill per month which translates to about a net savings of Rs 18 lakh per annum. The savings include the actual saving on the electricity units consumed along with the taxes and allied charges.

From Mar'20 to Feb'21 the actual bill paid by the institute has reduced drastically and the savings have increased manifold, due to the surplus solar power being fed back into the grid.

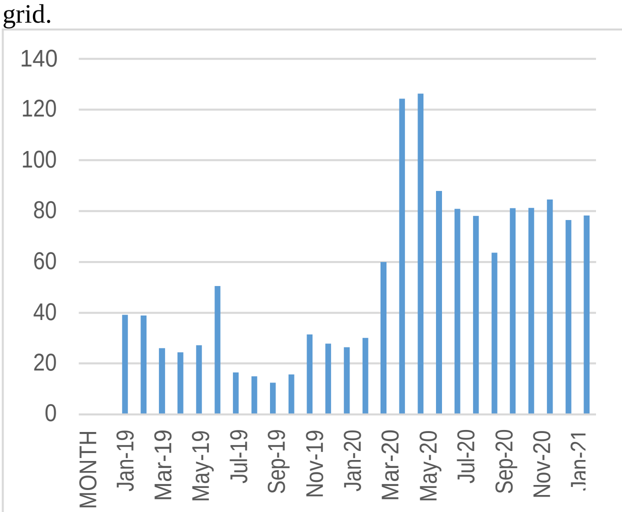

Fig10: % Monthly Savings

Percentage monthly savings are portrayed by Fig10. On an average the solar plant helps the institute save roughly 25% on its electricity bill. This amount has increased in the lockdown period. Though the savings for the months of April'20 and May'20 are more than 100% in terms of solar power generated, AIT still has to pay a minimum amount to MSEDCL.

4. Impacts and Improvements:

- The solar rooftop system fulfils 50% energy requirement of the institute.
- Extra electricity units generated are fed back to the Electricity Board by Net Metering System which results in a reduction of approximately 25% in the bill.
- The savings for the institution are to the tune of Rs 1.5 Lakh per month or Rs 18 Lakh per annum.
- Un-used roof space has been utilized productively.
- The shade generated by the solar panels helps to keep the top floor of the building cooler, further reducing the energy needs of the institution.
- The offset of carbon foot print is at about 1200 kg per day.
- Live solar projects and demonstrations for students generates an awareness amongst students regarding green energy while encouraging and facilitating them for working on Green energy projects.
- A Project has been completed and a Patent filed by Students of AIT on solar panel cleaning system.

5. Concerns and Challenges

- Poly crystalline Solar cells have an efficiency in the range of 15% which degrades over a period of time (Bhola and Bhardwaj, 2019; Kirmani and Kalimullah 2017; Pingle et al, 2010). This may bring down the number of electricity units generated by the solar panels. Manufacturers give a guarantee of 25 to 30 years, after which panels have to be replaced, as their efficiency reduces and makes the system economically unviable.
- Disposal/recycling of solar panels by the grid system user could be burdensome and problematic, as the users may not have resources or technical knowledge for the same.
- There is a provision in our contract with the vendor, whereby the responsibility for dismantling and disposal of the solar cell lies entirely with the vendor. This is as per the government directives. All the same, recycling of solar panels still remains a challenge.
- Disposal of underperforming Solar panels in landfill could endanger environment as the toxic materials like lead and chromium contained in the panels could, percolate out as the constituents of the panels break down. (Sharma, 2021; Nain P., Kumar A., 2020; Gunerhan 2009; Tsoutsos T., 2005).

- Since most of the solar cells in use today around the world, have been deployed after 2000, the panels that have deteriorated and need to be disposed off are few and far in between. Nevertheless, we ought to be prepared for better disposal and recycling of solar panels (Peter Majewski et al, 2021; Maani et al 2020; Xu et al, 2018; Fthenakis, 2000).

6. Conclusions

- The paper aims to create awareness and encourage the use of renewable green energy resources for generating power, especially the Grid Connected Roof Top Solar System.
- It also provides information about the ways in which the institutes can provide opportunities to students for innovation and understanding the implications of using renewable environmentally friendly technologies.
- The Grid Connected Roof Top Solar Projects are becoming popular and are a viable solution to cost cutting. Government has also taken good initiatives and is providing subsidies for the same. (Rakesh Ranjan 2021; Department of Additional Sources of Energy, Government of Uttar Pradesh; Sources: https://www.seci.co.in/upload/static/files/FAQs_Grid-Connected-Solar-Rooftop-Systems(1).pdf)
- The rooftop solar system at AIT generates 360,000 units of electricity annually and will offset 10,950 tonnes of carbon dioxide over next 25 years.
- With the execution of the grid connected Roof Top Solar System, apart from continued economic savings, the major compensation is towards reducing the carbon foot print, thereby contributing to sustained development with green technology.

7. Future Plans

Building a 100kW Solar Power Plant over our Rain Water Harvesting pond, is in the pipeline. This project will be an off-grid project and will cater to the needs of the upcoming boy's hostel.

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