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Cost Benefit Analysis of VVIT Campus Energy Using Python

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ABSTRACT

The renewable energy sources take part significant role in electricity generation. The rooftop solar system is installed by domestic, industrial and commercial consumers because of its advantages. In this paper, an economic analysis has been carried out to study the financial parameters by considering different blocks realistic load of the VVIT campus. The analysis helps the consumer for effective utilization of energy resources, the opportunities for energy saving with energy efficient equipment's and to reduce the electricity tariff. A Python program has been developed for rooftop solar mathematical model to determine the different parameters for analysis like the energy consumption of different blocks with and without solar, cost benefit, payback period and reduction in CO_2 *emissions which enables the consumers to switching from conventional energy system to rooftop solar system.*

Index Terms – *Economic Analysis, Energy Consumption, Rooftop Solar System and Python.*

1. INTRODUCTION

The wind and solar renewable energy resources are promising for generous and ample electricity generation of the power system worldwide. A mathematical model of PV array based on particle swarm optimization and incremental conductance algorithm coordination control has been discussed to improve the output efficiency PV array [1]. A method for reactive power management has been discussed with the voltage rise and reverses power flow issues, when residential solar panels generate excess energy than the local load requirement [2]. A Genetic algorithm based optimal solution with rooftop solar photo voltaic system approach has been presented for sizing and location of the solar PV with power loss minimization as the objective for a 162 bus Kabul distribution network [3]. The two different calculation tools have presented for economic analysis of PV projects with respect to atmosphere conditions of Gulf Cooperation Council countries. One tool is the economic analysis calculator and the other tool is the solar advisory model software. Also, the significance of renewable energy costs on PV projects has been discussed [4].

A multifunctional observer based control method has been presented for grid connected solar energy system with distribution static compensator [5]. A scheme has proposed to select the best battery size and converter unit along with the location of a central battery storage system [6]. An agent based modeling by considering the social, technical, environmental and economic aspects to evaluate the diffusion of rooftop PV systems on existing buildings for different PV module technologies has discussed [7-11].In this paper, A Python program has been developed for rooftop solar mathematical model to study the financial parameters by considering different blocks realistic load of the VVIT campus which enables the consumers to switching from conventional energy system to rooftop solar system.

2. MATHEMATICAL MODEL

The mathematical expressions of rooftop solar system [12] has been considered to estimate the energy consumed in a day based on the different types, rating and quantity of the loads in the VVIT campus along with number hours, the total PV generation capacity required along with the solar panels, batteries and the size of inverter. Also, the cost of solar panels, batteries, inverter and controller are considered during the cost benefit analysis. Further, the time required for the repayment of the investment i.e payback period has been estimated. Finally, the CO_2 emission reduction has been calculated as per the guidelines of central electricity authority. The technical, financial and environmental parameters obtained from these calculations are used to take the necessary steps as a part of green energy campus

3. PYTHON

In general the MATLAB has been used in many applications by electrical engineers more specific for power systems computations. The new open source language Python plays an important role in all the fields because of its simplicity, easy to learn syntax and also competitive with MATLAB. Python is a commonly used scripting language which enables engineers and researchers to solve complex problems interactively. Python is intrinsically object oriented open source language. It has strings, lists, dictionaries, functions, classes, and more as objects. These things have their own members and methods that summarize its functions and information. There are a large number of the libraries available to Python for Power System computations. The most potential modules including NumPy, SciPy, Matplotlib, Pylon, PyPower, Minpower are standard libraries used for Power System computations [13].

4. RESULTS AND ANALYSIS

In this section, the calculations for cost benefit analysis of rooftop solar PV system has been discussed with numerical example as VVIT campus loads. The campus has six blocks. The type of load, power rating and number of devices along with total load of block-A, B, C, D, central and new blocks are given in table I to table VI respectively. A Python code is developed to compute the count of solar panels, batteries required and also the benefit acquired in terms of money by switching to solar power. The costs of different devices are considered during the analysis from the literature [14-16] along with subsidy of 40% and the electricity tariff is Rs.6 per unit. The detailed calculations of each block are presented along with tables.

Table I Load Details of Block-A

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
8	40	114	Light	36480
8	60	174	Fan	83520
4	1830	50	AC	366000
4	105	142	Systems	59640
5	60	16	Laptops	4800
3	100	30	Sockets	9000
8	15	4	Ex-fans	480

Energy consumed in a day =559.92 kWh
Solar panels power rating = 559.92/ (7*0.8) =99.98kW
The solar panels required = 99.98*1000/250=400
Solar panels cost = (400*13100) =Rs 5240000
Total batteries required = 559.92*3*1000/(12*220*0.5) = 1273
Total cost of batteries = 1273*12000=Rs 15276000
Size of Inverter = (25000/1.7) = 14705.88 W
Inverter Cost = (14705.88*7.4) = Rs 108823.5

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Total cost of equipment = 5240000+15276000+4500+108823.5= Rs 20629323.5
The total cost of equipment with subsidy = 20629323.5-8251729.4 = Rs 12377594
Total electricity bill without solar for 25years =Rs 30655620
Total profit with solar power = 30655620-12377594 = Rs.18278026
Payback period = (12377594/30655620) *25 = 10.09 years.
The reduction of CO_2 emission = (559.92*0.82*365*25)/1000 = 4189.60 tons

Table II Load Details of Block-B

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
8	40	148	Light	47360
8	60	155	Fan	74400
4	1830	54	AC	395280
4	105	93	Systems	39060
5	60	11	Laptops	3300
3	100	40	Sockets	12000
8	5587	1	Lift	44696
8	15	5	Ex-fan	600

Energy consumed in a day =616.96 kWh
Solar panels power rating = 616.96/ (7*0.8) =110 kW
The solar panels required = 110*1000/250=440
Solar panels cost = (440*13100) =Rs 5764000
Total batteries required = 616.96*3*1000/(12*220*0.5) = 1402
Total cost of batteries = 1402*12000=Rs 16824000
Size of Inverter = (25000/1.7) = 14705.88 W
Inverter Cost = (14705.88*7.4) = Rs 108823.5
Total cost of equipment = 5764000+16824000+4500+108823.5= Rs 22701323.5
The total cost of equipment with subsidy = 22701323.5-9080529= Rs 13620794
Total electricity bill without solar for 25years =Rs 33778560
Total profit with solar power = 33778560-13620794 = Rs.20157766
Payback period = (13620794/33778560) *25 = 10.08 years.
The reduction of CO_2 emission = (616.96*0.82*365*25)/1000 = 4616.40 tons

Table III Load Details of Block-C

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
8	40	169	Light	54080
8	60	198	Fan	95040
4	1830	38	AC	278160
4	100	45	Sockets	18000
4	105	74	Systems	31080
5	60	46	Laptops	13800
4	3704	16	Machines	237056
8	5587	1	Lift	44696
8	15	4	Ex-fan	480

Energy consumed in a day =772.39 kWh
Solar panels power rating = 772.39/ (7*0.8) =137.92kW
The solar panels required = 137.9*1000/250=552
Solar panels cost = (552*13100) =Rs 7231200
Total batteries required = 772.39*3*1000/(12*220*0.5) = 1755
Total cost of batteries = 1755*12000=Rs 21060000
Size of Inverter = (25000/1.7) = 14705.88W

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Inverter Cost = (14705.88*7.4) = Rs 108823.5
Total cost of equipment = 7231200+21060000+4500+108823.5=Rs 28404523.5
The total cost of equipment with subsidy = 28404523.5-11361809.4 = Rs 17042714
Total electricity bill without solar for 25years =Rs 42288352
Total profit with solar power = 42288352-17042714 = Rs 25245638
Payback period = (17042714/42288352) *25 = 10.07 years.
The reduction of CO_2 emission = (772.39*0.82*365*25)/1000 = 5779.40 tons

Table IV Load Details of Block-D

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
8	40	125	Lights	40000
8	60	158	Fans	75840
4	1830	38	AC	278160
5	105	6	Systems	3150
4	723	17	Machines	49164
5	60	76	Laptops	22800
3	100	30	Sockets	9000
8	15	4	Ex-fans	480

Energy consumed in a day =478.59 kWh
Solar panels power rating = 478.59/ (7*0.8) =85.46kW
The solar panels required = 85.46*1000/250=342
Solar panels cost = (342*13100) =Rs 4480200
Total batteries required = 478.59*3*1000/(12*220*0.5) = 1088
Total cost of batteries = 1088*12000=Rs 13056000
Size of Inverter = (25000/1.7) = 14705.88 W
Inverter Cost = (14705.88*7.4) = Rs 108823.5
Total cost of equipment = 4480200+13056000+4500+108823.5=Rs 17649523.5
The total cost of equipment with subsidy = 17649523.5-7059809.4 =Rs 10589714
Total electricity bill without solar for 25years =Rs 26202802
Total profit with solar power = 26202802-10589714 =Rs 15613088
Payback period = (10589714/26202802) *25 = 10.10 years.
The reduction of CO_2 emission = (478.59*0.82*365*25)/1000 = 3581.04 tons

Table V Load Details of Central Block

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
8	40	126	Lights	40320
8	60	130	Fans	62400
6	1830	8	AC	87840
6	105	44	Systems	27720
6	60	10	Laptops	3600
4	100	20	Sockets	8000
8	15	2	Ex-fans	240
6	10	66	LEDs	3960
6	5100	2	Stand AC	61200
2	5000	5	Cassette AC	50000
6	4000	1	Central AC	24000

Energy consumed in a day =369.28 kWh
Solar panels power rating = 369.28/ (7*0.8) =65.94 kW
The solar panels required = 65.94*1000/250=264
Solar panels cost = (264*13100) =Rs 3458400

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Total batteries required = 369.28*3*1000/(12*220*0.5) = 839
Total cost of batteries = 839*12000=Rs 100680000
Size of Inverter = (25000/1.7) = 14705.88 W
Inverter Cost = (14705.88*7.4) = Rs 108823.5
Total cost of equipment = 3458400+100680000+4500+108823.5=Rs 13639723.5
The total cost of equipment with subsidy = 13639723.5-5455889.4 =Rs 8183834
Total electricity bill without solar for 25years =Rs 20218080
Total profit with solar power = 20218080-8183834 = Rs 12034246
Payback period = (8183834/20218080) *25 = 10.11 years.
The reduction of CO_2 emission = (369.28*0.82*365*25)/1000 = 2763.13 tons

Table VI Load Details of New Block

No. of Hours (h)	Power Rating (W)	No. of Devices	Type of Load	Total Load (Wh)
4	60	352	Fans	84480
4	40	273	Lights	43680
2	2212	26	Machines	115024
3	1830	97	AC	532530
4	5000	10	Casette AC	200000
2	5000	4	Central AC	40000
4	5000	3	Stand AC	60000
8	5587	1	Lift	44696
8	15	4	Ex-fans	480

Energy consumed in a day =1120.89kWh
Solar panels power rating = 1120.89/ (7*0.8) =200.15 kW
The solar panels required = 200.15*1000/250=801
Solar panels cost = (801*13100) =Rs 10493100
Total batteries required = 1120.89*3*1000/ (12*220*0.5) = 2547
Total cost of batteries = 2547*12000=Rs 30564000
Size of Inverter = (150000/1.7) = 88235.29 W
Inverter Cost = (88235.29*7.4) = Rs 652941
Total equipment cost = 10493100+30564000+4500+652941= Rs 41714541
The total cost of equipment with subsidy = 41714541-16685816 = Rs.25028725
Total electricity bill without solar for 25years =Rs 61368727
Total profit with solar power = 61368727-25028725 = Rs 36340002
Payback period = (25028725/61368727) *25 = 10.19 years.
The reduction of CO_2 emission = (1120.89*0.82*365*25)/1000 = 8387.05 tons

The total VVIT campus calculation has been discussed below with respect to all blocks.

Total energy consumed in a day = 559.920+616.696+772.392+478.594+1120.89+369.280
= 3917.77 kWh
Solar panels power rating = 3917.77/ (7*0.8) =699.60 kW
The solar panels required =699.60*1000/250=2799
Solar panels cost = (2799*13100) = Rs 36666900
Total batteries required = 3917.772*3*1000/ (12*220*0.5) = 8905
Total cost of batteries = 8905*12000=Rs 106860000
Size of Inverter = (275000/1.7) = 161764.70 W
Inverter Cost = (161764.70*7.4) = Rs 1197058.78
Total cost of equipment = 36666900+106860000+4500+1197058.78= Rs 144728458
The total cost of equipment with subsidy = 144728458-57891383= Rs 86837075
Total electricity bill without solar for 25years =Rs 214498017
Total profit with solar power = 214498017-86837075 = Rs 127660942

Payback period = (86837075/214498017) *25 = 10.12 years.
The reduction of CO_2 emission = (3917.77*0.82*365*25)/1000 = 29314.7 tons

The summary of the calculations are represented in Fig.1 to Fig.4.From the Fig.1, it can be observed that the New block consumes more energy and Central block consumes less energy compared to other blocks. Also, the block-C consumption is close to New block and the block-D consumption is close to Central block. Further, the block-A and block-B consumption is close to each other. Therefore, the New block electricity tariff is more and Central block tariff is less compared to other blocks as shown in the Fig.2.Similarly, From the Fig.3, it can be observed that the profit in the New block is high and the profit in the Central block is low compared to other blocks. Finally, the CO_2 emission reduction is high in New block and it is low in Central block compared to other blocks as shown in the Fig.4.

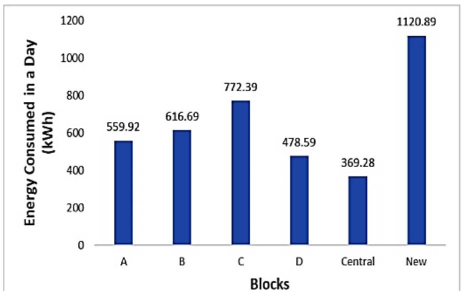


Fig.1Energy Consumed with respect to Blocks

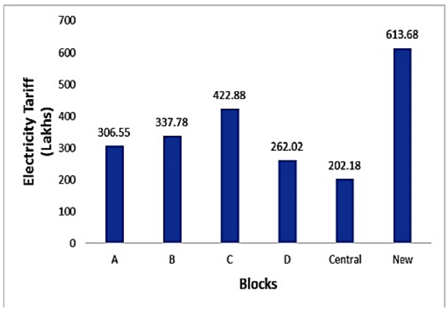
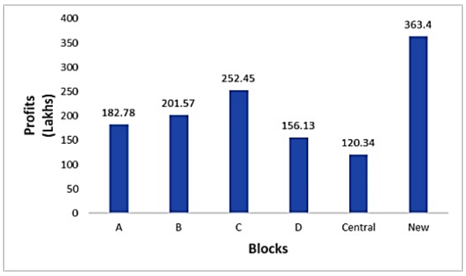


Fig.2 Electricity Tariff with respect to Blocks



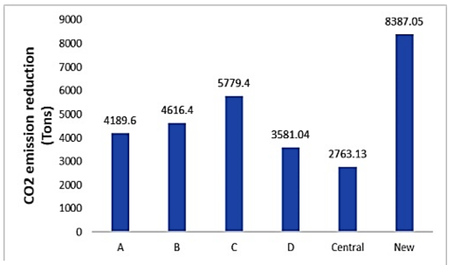


Fig.3 Profits with respect to Blocks

Fig.4 CO_2 Emission R

5. CONCLUSIONS

In this paper, an economic analysis has been carried out to study the financial parameters by considering different blocks realistic load of the VVIT campus. From the analysis, it can be observed that the New block consumes more energy and Central block consumes less energy compared to other blocks. Therefore, the New block electricity tariff is more and Central block tariff is less compared to other blocks. The profit and the CO_2 emission reduction is also more predominate in New block compared to other blocks. Finally, it can be observed that, the rooftop PV system total cost with subsidy is Rs 868.371 lakhs, along with a profit in 25 years is Rs 1276.609 lakhs. The payback period is 10.12 years with CO_2 emission reduction is 29314.7 tons for VVIT campus. Though the initial cost is high, switching to solar is beneficial in the long run. One more added advantage is that emission of carbon dioxide in the atmosphere is reduced considerably. The solar electric power plays a significant role in the future energy needs of Nation and the industry must take the necessary steps to make it affordable for utilities and consumers to select solar electric power compared to other forms of renewable energy sources.

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REFERENCES

1. J. Liu, J. Li, J. Wu and W. Zhou (2017), "Global MPPT algorithm with coordinated control of PSO and INC for rooftop PV array," *The Journal of Engineering*, vol. 2017, no. 13, pp. 778-782.
2. A. Safayet, P. Fajri and I. Husain (Nov.-Dec. 2017), "Reactive Power Management for Overvoltage Prevention at High PV Penetration in a Low-Voltage Distribution System," *IEEE Transactions on Industry Applications*, vol. 53, no.6, pp.5786-5794.
3. M. Ahmadi, M. E. Lotfy, R. Shigenobu, A. Yona and T. Senjyu(2018), "Optimal sizing and placement of rooftop solar photovoltaic at Kabul city real distribution network," *IET Generation, Transmission & Distribution*,vol.12, no. 2, pp. 303-309.
4. N. Saker, A. Al-Qattan, A. Al-Otaibi and A. Al-Mulla(2018), "Cost–benefit analysis of rooftop photovoltaic Systemsbased on climate conditions of Gulf Cooperation Council countries," *IET Renewable Power Generation*,vol.12, no. 9, pp. 1074-1081.
5. P. Shah and B. Singh(Sept. 2019), "Adaptive Observer Based Control for Rooftop Solar PV System," *IEEE Transactionson Power Electronics*, vol. 35, no. 9, pp. 9402-9415.
6. P. Hasanpor Divshali and L. Söder(Jan. 2019), "Improving Hosting Capacity of Rooftop PVs by Quadratic ControlofanLV-Central BSS," *IEEE Transactions on Smart Grid*, vol. 10, no. 1, pp. 919-927.
7. D. S. Schiera, F. D. Minuto, L. Bottaccioli, R. Borchiellini and A. Lanzini(2019), "Analysis of Rooftop Photovoltaics Diffusion in Energy Community Buildings by a Novel GIS- and Agent-Based Modeling Co-Simulation Platform," *IEEE Access*, vol. 7, pp. 93404-93432.
8. I. K. Nisa and I. Garniwa(2019), "Integrated Energy and Economic Model for Rooftop Photovoltaics on DistributionSystem," *2nd International Conference on High Voltage Engineering and Power Systems (ICHVEPS)*,Denpasar, Bali, Indonesia, pp.108-113.
9. H. Gong, V. Rallabandi and D. M. Ionel(2019), "Load Variation Reduction by Aggregation in a Community of Rooftop PV Residences," *IEEE Power & Energy Society General Meeting (PESGM)*, Atlanta, GA, USA, pp.1-4.
10. Shilpa N and Sridevi HR(2019), "Optimum design of Rooftop PV System for An Education Campus Using HOMER," *Global Conference for Advancement in Technology (GCAT)*, Bangaluru, pp.1-4, India.
11. Pavan Fuke, Anil Kumar Yadav, Ipuri Anil(2020), "Energy Performance and Economic Analysis of Different PVTechnologies for Grid Connected Rooftop PV System", *Power India International Conference (PIICON)*, IEEE 9th, pp. 1-5.
12. Piyush Sharma, Haranath Bojja and Pradeep Yemula(March 2016) "Techno-economic analysis of off- grid RooftopsolarPVsystem," *IEEE 6th International Conference on Power Systems (ICPS)*, pp.1-5.
13. Prabakaran S(2013), "Python for Power Systems Computation," *Proceedings of 3rd National Conference on Emerging Technologies in Electrical and Electronics Engineering (NCEEE)*, pp.202-206.
14. Solar Power Energy India, "Solar Charge Controller," Available:

http://www.solarpowerenergyindia.com/solar-charge-controller/
15. Urjakart, "Alpex Solar 250 Watt Panel," Available:
http://www.urjakart.com/alpex-solar-250-watt-solar-panel.html
16. CEA, "CO_2 Baseline Database for the Indian Power Sector," 2015, Available:
http://cea.nic.in/reports/others/thermal/tpece/cdm co2/user guide ver10.pdf/