DEVELOPMENT OF SOFTWARE TOOL FOR INTEGRATION OF GRID-TIED ROOFTOP SOLAR PHOTO VOLTAIC SYSTEM FOR THE DAIRY INDUSTRY

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Abstract: The population in India is continuously increasing, meanwhile, the demand for milk and hence electricity demand for processing milk and milk products has been continuously increasing. Hence, electrical energy is very crucial in the dairy industry. This paper focuses on the development of a software tool for the integration of Grid Tied Rooftop Solar Photovoltaic Systems (RTSPV). A computer program has been written in Python language in the pycharm platform to determine the size and performance of the RTSPV plant. An application software tool has been developed for the same. To validate the application software developed a case study is carried out at Shimoga Milk Union Limited (SHIMUL) dairy, Shimoga, Karnataka, India. The estimated parameters software are compared with the existing RTSPV System installed at JNN College of Engineering, Shimoga. The results obtained by the software are exactly matching with the existing plant. The suitability of the integration of the RTSPV system into the dairy industry is also analyzed in this paper.

Index Terms - Rooftop Solar PV System, Application software, Payback period, Reduction of carbon emission, Time of day Tariff.

I. INTRODUCTION

To foster sustainable, low-emission development, many countries are establishing ambitious renewable energy targets for their electricity supply. Because solar and wind tend to be more variable and uncertain than conventional sources, meeting these targets will involve changes to power system planning and operations. Grid integration is the practice of developing efficient ways to deliver variable renewable energy (VRE) to the grid. [11]. Integrating distributed photovoltaic (PV) solar power results in unique benefits and challenges compared to the integration of utility-scale wind and solar power. Significant localized growth in PV can raise concerns such as voltage violations and reverse power flow in low-voltage distribution systems. However, various studies have shown that positive impacts (e.g., reduced line losses and avoided generation costs) can also result from distributed PV [12]. Deploying distributed PV can reduce transmission and distribution line losses, increase grid resilience, lower generation costs, and reduce requirements to invest in new utility generation capacity. Distributed PV systems can also mitigate reliability issues experienced in developing areas by providing standby capacity capable of offering stable power during times of poor power quality [12]. In most electric utility systems, power flows in one direction, from centralized generators to substations, and then to consumers. With distributed generation (DG), power can flow in both directions. Most electric distribution systems were not designed to accommodate widespread DG and two-way flow of power. For distribution feeder circuits that are long and serve rural or developing areas, even small amounts of PV may influence system parameters if the load and PV generation are not closely matched [13]. The dairy industry plays a major role in handling the abundant quantity of perishable liquid milk. Which has to be processed or converted into valuable products. This process demands a large amount of electrical energy, which leads to a higher production cost. There is a serious concern to minimize the use of electrical energy from the grid to save the cost of electrical energy and a major concern to preserve natural resources thereby minimizing global warming. Electrical power is used throughout the dairy industry to drive the process, compressed air systems, motors, fans, pumps, lighting, and HVAC systems [3]. In addition to this, electrical power is used for cooling, freezing, and cold storage. Refrigeration in dairy plants accounts for about **55 to 60 %** of total electrical energy consumed. A diesel generator is also used as a captive power generation. In absence of grid power, diesel generator produces the electrical energy required for the dairy industry. As per the primary data collected from SHIMUL dairy, the diesel generator consumes around **800 to 850** liters of diesel. Further, the dairy industry consumes an average electrical energy of **2, 50,000 units** per month and procures **1, 50,000** liters of milk per day. To reduce the energy drawn from the grid and reduce carbon emissions, the integration of rooftop

solar photovoltaic systems with grid connection is highly essential. Given the above, the present study has been carried out with the following objectives.

a) To incorporate the decentralized energy technology (RTSPV) to meet the demand of the dairy industry.
b) To develop a software tool for integration of Grid Tied RTSPV to estimate different equipment and devices and their Performance.
c) To provide energy security for the dairy industry with due environmental consideration.

II. DEVELOPMENT OF SOFTWARE TOOL :

The software tool is developed to determine the components and their rating, and the investment required for installing the RTSPV system based on the average number of units required per month or the rooftop area available for installing the solar power plant. It is also used to estimate the savings and reduction in carbon footprint.
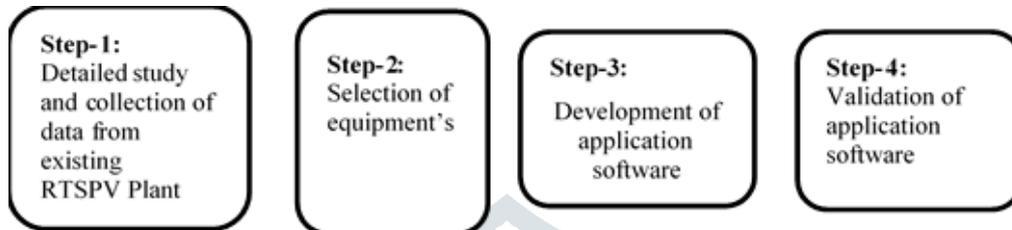
METHODOLOGY:

Figure 2.1: Methodology used for the Development of software for integration of RTSPV system:

The above block diagram represents stepwise methods for the development of software tool

Step-1: Detailed study of existing RTSPV System:

A 400 kW RTSPV System installed (Tata power solar, Bangalore) at JNN College of Engineering (JNNCE), Shimoga; Karnataka, India has been studied in detail. The monthly and annual generation data for the past year have been recorded. Annual electricity consumption details are collected to analyze the performance of the plant and the energy demand of the plant respectively. Further, various components such as the number of solar panels based on their power rating, inverters with their rating, rating of the AC distribution board, length, and size of the underground cable from the AC distribution board to the LT side of the transformer and energy that can be generated at a proposed site has been observed.

Step-2: Selection of Equipment:

After studying the existing plant, data is collected based on the standard ratings and specifications of PV modules, inverters, ACDB, and cables from various sources, which are available in the market. An algorithm is developed for calculations related to the design of the RTSPV plant and all the theoretical calculations of the design were carried out.

Step-3: Development of application software to estimate RTSPV plant:

Around 2000 lines of code are written to develop a computer program using the python programming language, which could accept the required inputs from the user and provide a detailed estimation of the RTSPV plant. To make the program more interactive and easily accessible for the user, a graphical user interface (GUI) is designed using the Tkinter toolkit of the python programming language. The developed Software tool estimates the total electrical energy generation at a given site based on the following assumptions. The number of units generated per kW per day is 4 units, this yield is assumed based on the actual generation of 400 kW RTSPV system installed at JNNCE, Shimoga Karnataka, India. Roof Top Area of 100 Sq.ft is considered for installing a 1 kW capacity solar PV system. For the calculation of carbon footprints, 0.860 kg/ kWh is considered the life of the plant is assumed to be 25 years from the date of installation.

Step-4: Validation of application software:

The results obtained from the developed application software are validated with the existing RTSPV system installed at JNNCE.shimoga. The results are matching with the existing plant.

III. Input to software tool for estimation of RTSPV System components:

To run the software tool developed, entry of customer details is mandatory. To determine the different components required to install and integrate the RTSPV System into the grid, two options are included in the program, one is the roof area option and the other is the electricity bill option. The customer has to enter the details of only one option based on the details available to them. By enabling either the roof area option in the data entry page or the electricity bill option, the Customer has to enter the details as shown the table 3.1 (a) or 3.1 (b). If one option will be enabled then the other option will be automatically disabled.

3.1 (a) Input format for Software Tool: when Rooftop area is enabled.

Figure 3.1: Input format for Software Tool: when the Rooftop area is enabled.

The above image shows the format when the rooftop area option is enabled. The software tool is asking for the number of buildings available for installing the solar panels, the area of buildings, the height of the parapet wall, neighboring buildings, rating of panels, distance between ACDB to transformer LT, and cost/kW. Then, by operating calculate button, it will generate the report. This report can be downloaded and also it can be sent to the customer's e-mail, otherwise, it will be available in the output file. The computer tool will also generate the bar chart of annual energy generated v/s time in months and energy generated in units v/s time in years, based on the assumption that, the annual average generation of 4 units/kW/day and reduction in efficiency by % per year.

3.1(b) Input format for computer Tool: when Electricity bill is enabled.

Figure 3.2: Input format for computer Tool: when Electricity bill is enabled.

The above image shows the format when the electricity bill option is selected. The computer tool asks for the average units consumed per month, the distance between ACDB to transformer LT, panel rating, and cost/kW. After entering the above details and further, Then, by operating calculate button, it will generate the report. This report can be downloaded and also it can be sent to the customer's e-mail, otherwise, it will be available in the output file. The computer tool will also generate the bar chart of annual energy generated v/s time in months and energy generated in units v/s time in years, based on the assumption that, the annual average generation of 4 units/kW/day and reduction in efficiency by % per year.

IV. ENERGY CONSUMPTION AND SIZING OF RTSPV SYSTEM

For the analysis of the present energy consumption pattern in the SHIMUL dairy industry, a detailed study of a one-year electricity bill on monthly basis has been recorded. By knowing the average energy consumed/month, sanctioned demand of 600 kVA, at a power factor of 0.85, and as per the regulations of Mangalore Electricity Supply Company (MESCOM), it has been calculated and proposed to install 510 kW RTSPV system to meet the electrical energy demand. The electrical energy consumption details/month for the year 2021, proposed electrical energy generation details by installing RTSPV, the average energy consumption and the percentage reduction in energy consumption from the grid have been tabulated in table 4.1. Further, to estimate the capital investment required, payback and savings during the guarantee period, and equipment required, a computer software tool is developed and it is validated with the RTSPV system at JNNCE, Shimoga. Table 4.2 shows the annual slot-wise energy consumption in the dairy industry and it has been observed that by installing RTSPV the energy charges for slot one (6:00 AM to 10:00 AM) throughout the year can be reduced as per the time of day tariff (TOD) applicable to HT customers.

Table 4.1: Energy consumption and solar power generation details at the proposed site

Month Year	Energy consumed in kWh	The electrical power generation	Percentage (%) Reduction in energy consumption from the grid
Jan-22	1,92,960	73,784	38
Feb-22	1,93,910	70,686	36
Mar-22	2,33,160	77,316	33
Apr-22	2,27,400	68,429	30
May-22	2,13,720	62,335	29
Jun-22	1,32,480	45,581	34
Jul-22	1,88,010	40,163	21
Aug-22	1,96,680	44,842	23
Sep-22	2,00,820	52,874	26
Oct-22	2,23,470	58,803	26
Nov-22	2,20,890	60,512	27
Dec-22	2,18,790	68,901	31
Total	24,42,290	7,24,226	--
Average	2,03,524	60,352	30

Chart No.4.1: Energy consumption and Generation details at the proposed site
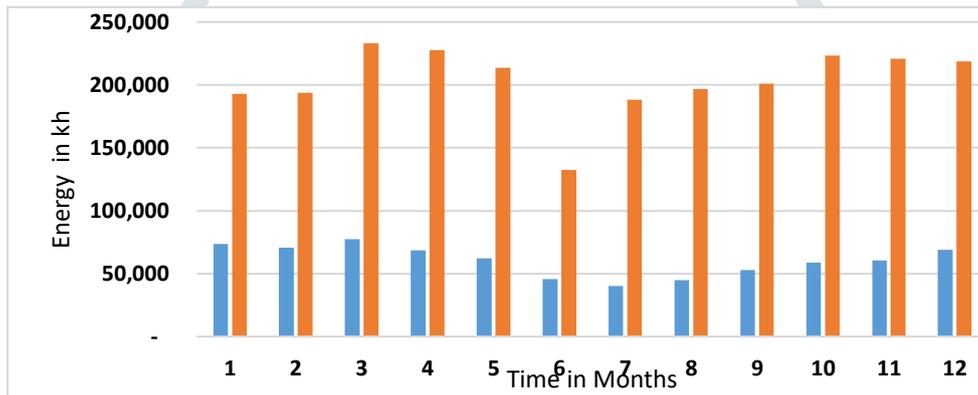
Table-4.2: Slot-wise energy consumption details

| Month	6-10 hrs(x1)		10-18 hrs(0)		18-22 hrs(x1)		22-04 hrs(x-2)		
	Units	Rs	Units	Rs	Units	Rs	Units	Rs	Units consumed
Jan-21	41,430	41,430	70,560	o	28,290	28,290	52,680	-1,05,360	1,92,960
Feb-21	35,570	35,570	75,960	o	30,030	30,030	52,350	-1,04,700	1,93,910
Mar-21	42,120	42,120	91,440	o	35,190	35,190	64,410	-1,28,820	2,33,160
Apr-21	43,110	43,110	86,100	o	35,340	35,340	62,850	-1,25,700	2,27,400
May-21	37,740	37,740	80,550	o	34,110	34,110	61,320	-1,22,640	2,13,720
Jun-21	26,220	26,220	33,000	o	19,110	19,110	54,150	-1,08,300	1,32,480
Jul-21	38,460	38,460	63,420	o	30,480	30,480	55,650	-1,11,300	1,88,010
Aug-21	39,480	39,480	70,590	o	31,890	31,890	54,720	-1,09,440	1,96,680
Sep-21	40,260	40,260	70,500	o	32,910	32,910	57,150	-1,14,300	2,00,820
Oct-21	41,640	41,640	82,200	o	36,360	36,360	63,270	-1,26,540	2,23,470
Nov-21	39,030	39,030	85,140	o	35,850	35,850	60,870	-1,21,740	2,20,890
Dec-21	39,990	39,990	82,410	o	35,220	35,220	61,170	-1,22,340	2,18,790
Total	4,65,050	4,65,050	8,91,870	0	3,84,780	3,84,780	7,00,590	-14,01,180	23,09,810
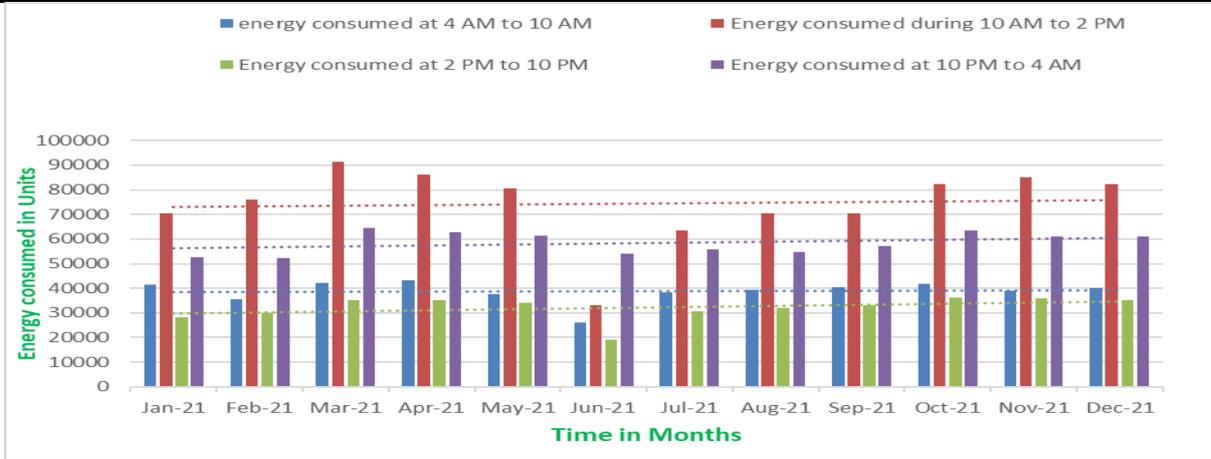
Chart 4.2: Slot-wise energy consumption Slot-wise time in Months
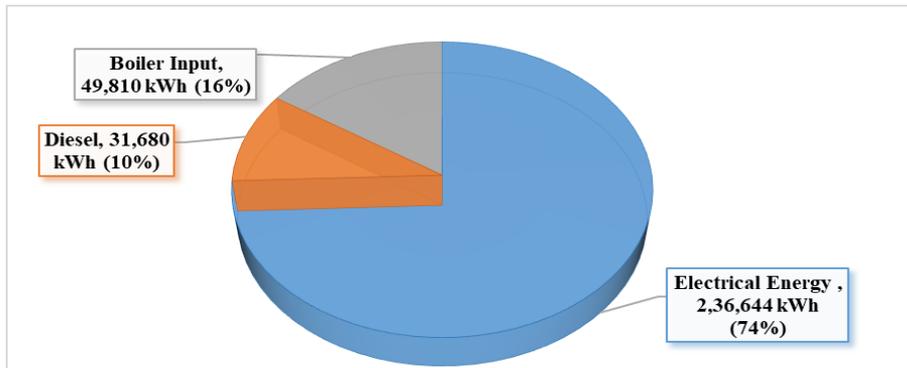
Chart 4.3: Percentage of equivalent electrical energy consumed in kWh.

Chart 4.3 shows the details of the Percentage of equivalent electrical energy consumed in kWh Per annum by different modes of energy. It has been observed that at the boiler, diesel generator, and electrical devices consume equivalent electrical energy of 16%, 10%, and 74% of the total energy consumed by the industry respectively. Integration of solar plants reduces the considerable amount of power consumption of industry considerably.
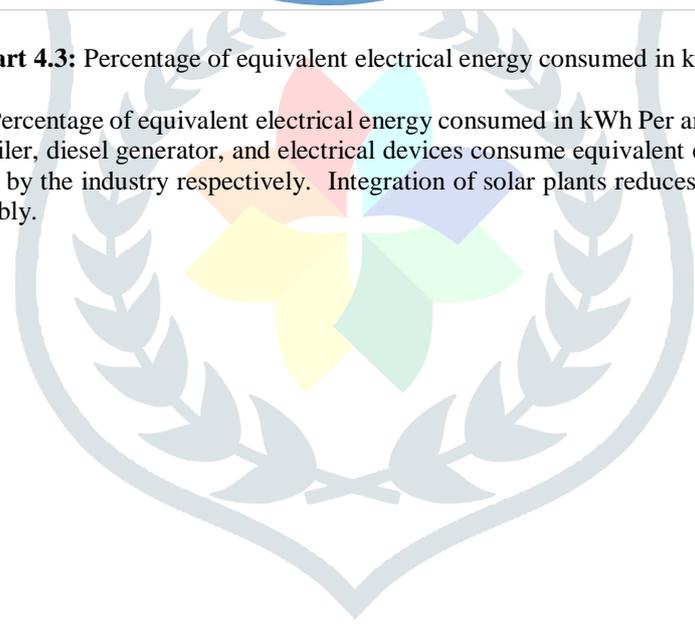
V. Results and discussion:

- **The sample output file generated from a software tool:**

" ESTIMATION OF ROOFTOP SOLAR PV SYSTEM "

Customer Details:

Date : 22-Feb-2023

Company/Institute Name : jnnce

Address : shimoga

Email : nga_ee@jnnce.ac.in

Number of Strings : 18-20 Panels to be Selected/String
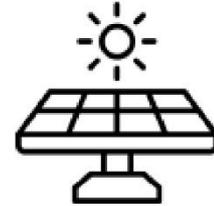
Inverter Capacity & Inv to ACDB Cable Size :

S.No	Inverter Capacity	Qty	Cable Size Inv-ACDB	Isolator Rating
01	100 kW, 415V, MPPT	0	0	0
02	50 kW, 415V, MPPT	0	0	0
03	25 kW, 415V, MPPT	1	3.5Cx16 Sq.mm (1 No.)	125A, MCB Type, 4P 415V (1 No.)
04	20 kW, 415V, MPPT	1	3.5Cx16 Sq.mm (1 No.)	125A, MCB Type, 4P 415V (1 No.)

AC Distribution Board 2 IN/1 OUT :

S. No	Components	Specifications
01	MCCB	250A, 415V, 4POLE, 10KA Breaking Capacity
02	Multi Function Meter	CL-0.5, 3PH 4W 415V
03	CT	100/5A CL 0.5
04	PT	415/110V
05	Bus Bar	100A, 415V, 3PN Aluminium

Total Current : 80 Amps

Size of the Cable from ACDB to Grid : 3.5Cx240 Sq.mm

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RTSPV Estimation Report

Total Output Parameters of the RTSPV System :

S. No	Parameters
01	Total Rooftop Area : 4167 Sq.Feet
02	Total Utilized Rooftop Area : Not Applicable Sq.Feet
03	Total Capacity of the Plant : 41.67 kW
04	Total Number of Panels : 128 No.
05	Inverter - 100 kW, 415V AC, 50Hz, MPPT : 0 No.
06	Inverter - 50 kW, 415V AC, 50Hz, MPPT : 0 No.
07	Inverter - 25 kW, 415V AC, 50Hz, MPPT : 1 No.
08	Inverter - 20 kW, 415V AC, 50Hz, MPPT : 1 No.
09	Total Number of AC Distribution Board : 1 No.
10	Total Annual Electricity Generation : 65933.61 kWh
11	Total Electricity Generation over 25 years : 1464903.98 kWh
12	Total Cost of the Plant : 0.21 Cr.
13	Estimated Payback Period : 4 Years & 10 Months
14	Estimated Post Payback Profitability : 1.76 Cr.
15	Investment on FD over 25Years of 6.5% Interest : 1.01 Cr.
16	Carbon Emission Reduction over 25 Years : 1201 Tonnes
17	Planting Trees over 25 years : 1921 No.

RTSPV Estimation Report

Monthly Average Generation

Annual Average Generation, 2021-2045

Page 3
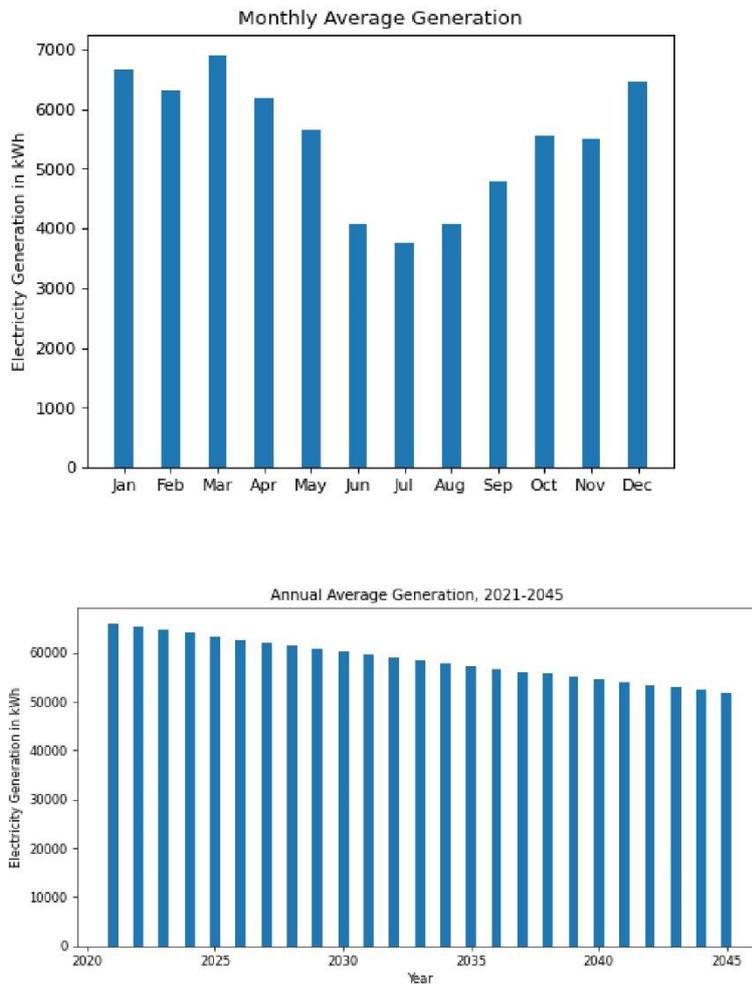
- **Validation of the software tool developed:**

To validate the software developed with the existing solar plant at the site, the components listed, and the performance of the solar plant are compared. Table 6.1 illustrated the comparison.

SL. No	Area	Existing		Estimated by software		Remarks
		Electrical block-1	Electrical block-2	Electrical block-1	Electrical block-2	
		General information				
1	Rooftop area (A) in Sq. feet.	107.2×27.2 = 2915.84	98.4×36.08 = 3312.14	2915.84	3312.14	The actual Length and width of the rooftop of the building were measured and assigned to the software.
2	Height of a Parapet wall (P) in feet	3.5	3.5	3.5	3.5	The actual height of the parapet wall of the rooftop of the building was measured and assigned to the software
3	Utilized area= (A-P) in Sq. feet.	2145	2580	2145	2580	Utilized area = (Total rooftop area available – an area of a parapet wall)
Details of existing components and the components estimated by software:						
SL. NO	Particular	Existing components		Components estimated by the software		Remarks
		Electrical block-1	Electrical block-2	Electrical block-1	Electrical block-2	
4	The capacity of the plant in kW	19.5	19.2	21.4	21.2	Overhead Water tanks are installed on the roof of both buildings to meet the water requirements of the dept. Hence, the actual capacity of the plant is less than the estimated value.

5	Number of Solar panels of 325 kW capacity	60	59	66	62	Overhead Water tanks are installed on the roof of both buildings to meet the water requirements of the dept. Hence, the actual panels installed are less than the estimated value.
6	No solar panels per string.	20,20,20	20,20,19	18-20	18-20	Actual panels/string matching with the estimated panels per string.
7	MCCB	250A, 415V, 4POLE, 10KA Breaking Capacity		250A, 415V, 4POLE, 10KA Breaking Capacity		Matching for ACDB
8	Multi-function meter	CL-0.5, 3PH 4W 415V		CL-0.5, 3PH 4W 415V		Matching for ACDB
9	Metering Current transformer in Ampere	250/5A CL 0.5		100/5A CL 0.5		Matching for ACDB
10	The potential transformer in Volts	415/110V		415/110V		Matching for ACDB
11	Bus bar	100A, 415V, 3PN Aluminum		100A, 415V, 3PN Aluminum		Matching for ACDB
12	AC Distribution Board (ACDB) Rating	100A, 415V, 3PN Aluminum		100A, 415V, 3PN Aluminum		Matching for ACDB
13	Isolator	125A,4pole		125A,4pole		Matching for ACDB
14	Initial Investment in Rs	19,35,000=00		24,00,000=00		The actual investment is less than the estimated value.
15	Actual energy generated/annum	58,728 kWh		65,934 kWh		The actual generation is less than the estimated generation.
16	Revenue generated in Rs by solar plant @ 8.2Rs/unit	4,81,570		5,40,659		Revenue generated from estimated software is more than the actual energy generated by the plant because of higher plant capacity.
17	Payback period in years	4.01 years		4.4 years		The actual payback period Matches the estimated value.

Conclusions

The computer software tool developed Prescribes the integration of Grid Tied Roof Top Solar Photovoltaic System (RTSPV). A computer program has been written using Python language in the pycharm platform to determine the size of the RTSPV plant based on contract demand or average units consumed per month. For estimating the expected generation 4 units per kW per day is assumed instead of considering the solar data at the site. The results obtained are validated with the working RTSPV Plant installed (Tata power solar Bangalore) at JNN College of Engineering, Shimoga, Karnataka India, components estimated to install the RTSPV system by software tool are compared with actual components installed at the site which yields good result. The software tool so developed saves the time required for doing repeated calculations and is also helpful for analyzing the performance of the plant before installation. Although the above conclusions are made with special reference to SHIMUL dairy of Shimoga district, Karnataka state. The software tool so developed, in general, applies to any industry in India, by incorporating the radiation data in the program and could be used all over the world.

Acknowledgment

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Biographies:

N G Ajjanna received a bachelor's degree in Electrical and Electronics Engineering from Kuvepu University in 1995, and a master's degree in Energy System engineering from Visweswaraya Technological University in 2001. He is currently doing Research work in the field of Energy Management. Working as an Assistant Professor at the Department of Electrical and Electronics Engineering and coordinator of 400KW RTSPV system installed at JNNCE, Shimoga. His interesting areas include Energy Auditing, Energy conservation, DSM Techniques, and Renewable Energy Technologies. He has authored and published a Textbook on Energy Auditing and Demand Side Management.

Dr. H.B. Suresh received his B.E. degree in electrical and electronics engineering from Mysore University, India, and his M.E. in energy system engineering from Karnataka University, India. He pursued his Ph.D. program at Jawaharlal Nehru Technological University, India. Currently, he is working as a professor in the electrical and electronics engineering department, at JNNCE, Shimoga. He has presented various papers at conferences in India and published twelve papers in national and international journals and conference proceedings. Currently is guiding two candidates for the Ph.D. program. He is the coordinator for Biofuel Research, Information and Demonstration Centre (BRIDC), JNNCE, funded by Govt. of Karnataka. His areas of interest are sustainable energy technologies, energy conservation, and management, and renewable energy resources. He has delivered more than 100 invited technical talks.

Dr. L.K. Sreepathi received his B.E. degree in mechanical engineering from Bangalore University India in the year 1985. He pursued his M.Tech and Ph.D. programs at IIT Bombay from 1988 to 1994 in the area of thermal and fluid engineering. He is the former Vice-Principal of JNN College of Engineering, Shimoga. He has carried out several research projects funded by CSIR, MNES, AICTE, etc. His areas of interest are biomass gasification, passive cooling of the building, solar energy, rainwater harvesting, etc. He has successfully guided five Ph.D. students. Currently is guiding two candidates for the Ph.D. program. He has presented papers at various conferences in India and abroad and has published more than twenty-five papers in national and international journals and conference proceedings.

He was the coordinator for the Chiranthana Green Technology Centre and the BRIDC of the college. The canter is actively involved in promoting renewable energy devices, rainwater harvesting, and a sustainable and eco-friendly lifestyle among school/college students and the public. He has written booklets on roof water harvesting, solar water, solar photovoltaic cell, renewable energy sources, and a play on water harvesting in the Kannada language. He has traveled almost all parts of Karnataka state on a bicycle and has trekked in the Sahyadri and Himalayan mountains. He is residing in an eco-friendly house "VIBHA" along with his wife Mamatha and son Vishaka. The house has been featured in Discovery, National Geographic, other TV channels, and print media. Presently he is working as a green energy consultant and managing director of Malnadu Green Energy Industries.