Designing Experimental Setup For A Renewable Energy-Based Security System And Feasibility Analysis Using Retscreen Expert

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Abstract- *The global energy crisis is worsening day by day, so it is high time to focus more on renewable energy and reduce the dependency on fossil fuels. To promote the versatile use of renewable energy, a solar power-operated security system at Shahjalal University of Science and Technology is proposed in this paper. Some equipment of the security system was connected to the solar photovoltaic system as a part of an experimental setup to analyze the performance of the solar panels and to get an idea of the real-time market price of the solar equipment. Considering the result of the experimental setup, the total solar equipment and the total cost for the project were assumed. A feasibility analysis of the project was conducted through RETScreen Expert. The internal rate of return (IRR), net present value (NPV), and equity payback period are 6.1%, 19,787 BDT, and 18.1 years respectively, indicating its acceptability as a feasible project.*

Keywords- renewable energy, security system, feasibility analysis, RETScreen Expert, payback period, emission reduction, PV system.

I. INTRODUCTION

Energy is the driving force of a country's development, economic growth, and automation. Every aspect of our life requires the usage of energy. Some key areas where we can not survive without energy include transportation, food, lighting, communication, heating/cooling, etc. Bangladesh is a fast-growing developing country, and the annual energy demand in Bangladesh is reaching a record high. Bangladesh gets most of its energy from fossil fuels, and fossil fuels are not abundant in nature. So, for sustainable development, Bangladesh's government should pay more attention to exploiting other energy sources, for example, solar, hydro, wind, geothermal, and biofuels. Besides, Bangladesh is situated in an excellent geographical location which enables Bangladesh to receive solar radiation between 4 and 6.5 kWh/m^2 daily [1]

Much research has been conducted on the versatile use of solar PV modules. Ibrahim et al. [2] presented a solution to the electricity crisis in rural areas of Bangladesh. Their study shows that by setting up a PV micro-utility system, where users will get electricity for 5 hrs a day on a fee-for-service basis, many shop owners of a rural Bazar benefited. Hasan et al. [1] proposed a solar street lighting system for the SUST campus. The amount of CO^2 reduction and cost savings in a year are shown in the study. SHAKIR et al. [3] examined the average annual sunlight hours in Bangladesh and compared it with other developed countries like Germany and Spain, which are notable for their development in the renewable energy sector. Suitable locations for solar power plants are proposed based on the maximum efficiency factors like sunlight hours, cloud coverage limits, amount of solar radiation received, type of panel, etc. Mahmud [4] discussed the prospects of solar energy in Bangladesh. In the study, it is shown that electric vehicles can be charged from solar-based recharging stations, and irrigation pumps can be run by the solar system. Hossain et al. [5] discussed designing of a photovoltaic (PV) power generation (Off-Grid & Grid-Connected) system and estimated its feasibility for a proposed academic building at SUST. The study has found that though both approaches are feasible, the Grid- connected PV system is better than OFF-Grid in terms of the annual life cycle, emission savings, and net present value (NPV). Bhuiyan et al. [6] designed and studied a partially solar-powered electrical tricycle. By evaluating the performance, the study suggested that a partially solar-powered electrical tricycle is more economically sound than any other option.

Copious research was performed to analyze the different scopes of renewable energy, but limited research has been published on designing a solar energy-based security system. The study's main objectives are to develop a solar-operated security system and to conduct a feasibility analysis of the project through RETScreen Expert software.

II. METHODOLOGY

For the study of a renewable energy-based security system, first, the total load of the system was calculated. Then, some loads of the security system were connected to the solar panels, to evaluate the PV system's performance and get the real-time market price of solar equipment. After getting the performance result and cost of installing a solar system, the total number of solar equipment and total cost of setting up a renewable energy-based security system were determined. Lastly, a pre-feasibility analysis was conducted using RETScreen Expert (Version 8) software to assess the project's financial viability.

Figure 1 shows the components of solar energy-based security systems and how they are connected to one another.

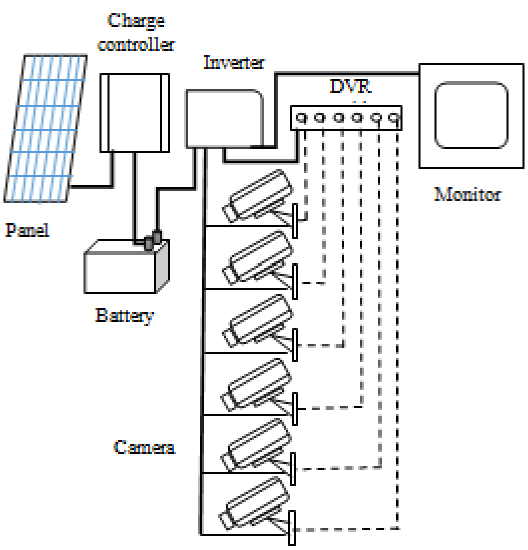


Figure 1: Component setup for solar system

III. SYSTEM SIZING

System sizing refers to calculating the adequate voltage and current ratings for each component of a solar system so that the components of the system can meet the electric demand of a facility. To perform the system sizing of the security system, the daily energy consumption by the system is required. Table 1 shows the daily energy consumption of the security system.

Table 1: Power consumption by the surveillance system

Load	**Quantity**	**Power for each (watt)**	**Using hour/day (h)**	**Energy consumption per day (Wh)**
Camera	**6**	**5**	**24**	**720**
Monitor	**1**	**25**	**12**	**300**
DVR	**1**	**30**	**24**	**720**
Light	**10**	**3**	**12**	**360**
Total				**2100**

In an experimental setup, only the cameras and lights (60 W) were chosen to run on solar energy, while the DVR machine and monitor (55 W) were selected to run on grid energy. So, sizing was conducted for cameras and lights only.

The roof-top of academic building 'C' of Shahjalal University of Science and Technology has been chosen for solar panels installation. According to Google Map the latitude and longitude of the location are 24.9 North and 91.9 East, respectively. The slope and azimuth of the solar panels are considered 45º and 0º, respectively.

A.Sizing of The Solar Array

The sizing of the array depends on the total energy required by the system. The losses are also needed to be considered to avoid under-sizing. Required energy R_e can be obtained by dividing the average daily consumption by the efficiency of all the components in the system.

$$R_e = \frac{\text{Daily power consumption}}{\text{overall components efficiency}}$$

$$R_e = \frac{P}{\eta_{comp.}} = \frac{720+360}{0.8} = \frac{1080}{0.8} = 1350 \text{ Wh}$$

Peak power is the ratio of (Re) and the average sun hour in that location. According to the RETScreen software climate database, the average sunshine in the Sylhet region is about 4.57 hr/day.

$$P_e = \frac{R_e}{\text{average sun hours}} = \frac{1350 \text{ Wh}}{4.57 \text{ h}} = 295 \text{ W}$$

Considering the rainy days and other environmental problems, we selected a total of 400 W solar panels (four 100-watt panels) for the experimental setup.

B. Sizing of Battery

Total power of the lights = 30W
Total power of cameras = 30 W
Operation hours of lights = 12 hr
Operation hours of cameras = 24 hr
Hours of autonomy = 1 day

Energy storage: The amount of rough energy storage required is equal to the multiplication of the total power demand and total operation hours in a day.

$E_{rough} = P \times H = (30\times12) + (30\times24) = 1080$ Wh

For safety, the obtained result is divided by the battery efficiency.

$$E_{safe} = \frac{\text{energy storage required}}{\text{battery efficiency}} = \frac{1080}{0.8} = 1350 \text{ Wh}$$

Capacity of the battery bank: The capacity of the battery bank is needed in ampere-hours and can be calculated by multiplying the required safe energy storage with hours of autonomy and then dividing by the DC voltage of the selected battery.

$$C = \frac{E(safe)\times \text{hours of autonomy}}{\text{voltage}} = \frac{1350 \times 1}{12} = 112.5 \text{ Ah}$$

For the setup, a 130 Ah battery was selected.

C. Sizing of Solar Charge Controller

The sizing of the charge controller can be obtained by multiplying the short circuit current of the modules by a safety factor F.s. The result gives the rated current of the charge controller I.

For 100W panel $I_{sc} = 6.69$A

I = Isc × F.s. = 6.69 × 1.25 A = 8.36A

The solar panels were connected in parallel, so the total array current was = 8.36*4 = 33.45 A, that's why we selected a 40 A charge controller.

D. Sizing of Inverter

The inverter's sizing depends on the total wattage of the energy consumed and the safety factor [7].

Inverter = power × safety factor

Total power for cameras and lights P= 60 Watt.

Inverters power $I_p = 60 \times 1.25$W = 75W

So, the inverter must be able to handle about 75 W at 220V AC. The output power of our installed inverter was 1000W.

IV. PERFORMANCE EVALUATION

After the complete setup of the system, some data, such as the current and voltage of the solar panels, were measured with the help of a clamp meter. And the radiation of the sunlight was also measured with the help of a pyranometer. The data were collected for five consecutive days, and it was observed that the solar panels get a significant amount of solar radiation each day except the 29th of September. Figure 2 illustrates the five days of radiation data.

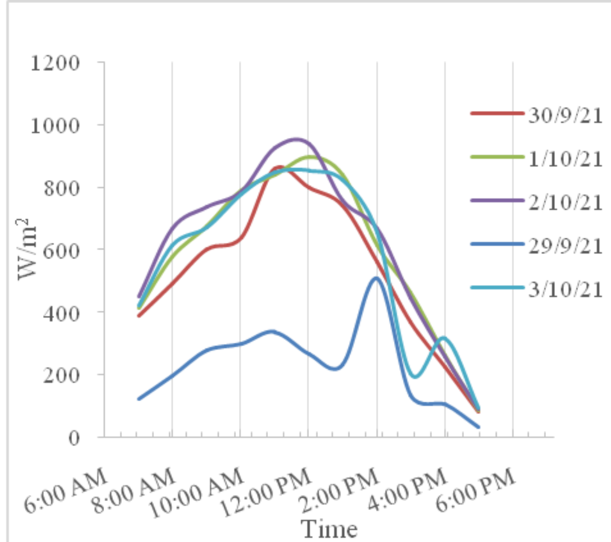


Figure 2: Solar radiation of five consecutive days

Current and voltage data of solar panels were measured and recorded at every 30 minutes intervals from 8 am to 5 pm. The data were collected from 29/9/2021 to 3/10/2021, and the data from 2/10/2021 are presented in Table 2.

Table 2: Output data of the 100 W solar panel

Date	Time	Voltage (V)	Current (A)	Power (W)	Energy (Wh)
2/10/2021	8.00 AM	14.38	1.44	20.71	10.35
	8.30 AM	14.75	2.15	31.64	15.82
	9:00 AM	15.12	2.85	43.09	21.55
	9:30 AM	15.14	3.23	48.81	24.41
	10:00 AM	15.15	3.60	54.54	27.27
	10:30 AM	15.06	3.78	56.83	28.42
	11:00 AM	14.96	3.95	59.09	29.55
	11:30 AM	15.04	4.03	60.52	30.26
	12:00 PM	15.11	4.10	61.95	30.98
	12:30 PM	15.08	3.75	56.55	28.28
	1:00 PM	15.05	3.40	51.17	25.59
	1:30 PM	14.73	2.70	39.70	19.85
	2:00 PM	14.41	1.99	28.68	14.34
	2:30 PM	14.54	1.99	28.85	14.43

	3:00 PM	14.66	1.98	29.03	14.51
	3:30 PM	14.35	1.54	22.09	11.05
	4:00 PM	14.03	1.10	15.43	7.72
	4:30 PM	13.77	0.74	10.21	5.11
	5:00 PM	13.51	0.38	5.17	2.59
Total					362.03

Total energy produced by all the four panels = 362 *4 = 1448 Wh.
So, the energy required by the cameras and lights (1350 Wh) was easily met by the solar panel's output (1448 Wh).

V. RESULTS AND DISCUSSION

The total load of the experimental setup was 60 watts, and the total load of the rest of the devices was 55 watts. So, for the rest of the devices, the same cost and the same solar equipment as the experimental setup were considered. Using RETScreen Expert software, the net present value (NPV), internal rate of return (IRR), and payback period were calculated to assess the feasibility of the project.

A. Cost Analysis

The total cost of the components of the solar system was considered according to the cost of the experimental setup.

Table 3: Cost of components of the PV system

Component & Type	Capacity	Quantity	Price (BDT)
Solar panel (mono-Si)	100 W	8	28000
Battery (Tubular)	130	2	26300
Charge Controller (PWM)	40 A	2	5000
Inverter (pure sine)	1000 W	1	6300
Cables (10 sq mm)			6200
Structure and setup			7000
Repair & maintenance		3% of PV cost	840

Considering the warranty and price, we assumed that the batteries and the inverter would need to be replaced one time, while the charge controller would need to be replaced two times during the life span (25 years) of the project.

B. Financial Analysis

Financial analysis is a very important part of the feasibility analysis of any project. The financial analysis worksheet of the software requires some parameters to include. For this reason, the inflation rate is considered 5.5% [8], the discount rate is 4% [9], and the per unit cost of electricity is considered 7.07 BDT [10]. The fuel and electricity escalation rates are 5.42% and 3.23%, respectively, calculated from the past data of the Bangladesh Energy Regulatory Commission (BERC). The project life is assumed to be 25 years. Based on these input variables, RETScreen software provides some outputs that have been shown in Table 4.

Table 4: Financial output variables from the RETScreen Expert.

Financial viability	Value
Pre-tax IRR-equity (%)	6.1
Pre-tax IRR-assets (%)	6.1
After-tax IRR-equity (%)	6.1
After-tax IRR-assets (%)	6.1
Equity payback (yr)	18.1
Net Present Value (NPV) (BDT)	19,787
Annual life cycle savings (BDT/yr)	1,267
Benefit-Cost (B-C) ratio	1.3

For this project, the net present value (NPV) is positive, which means the project is financially and economically feasible [11]. Also, the value of the internal rate of return (IRR) is greater than the value of the discount rate, which is another sign of an economically feasible project. The payback period is also satisfactory, which is 18.1 years in a project life span of 25 years. The payback period of the project is shown in Figure 3.

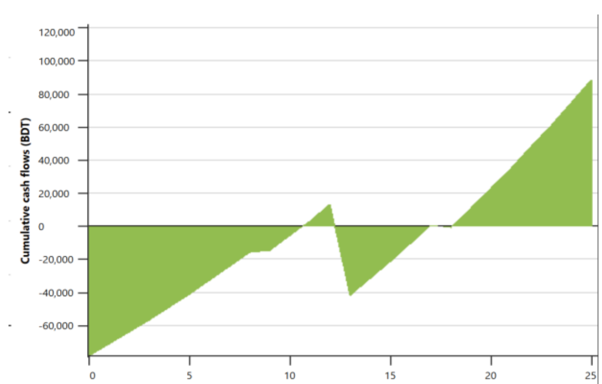
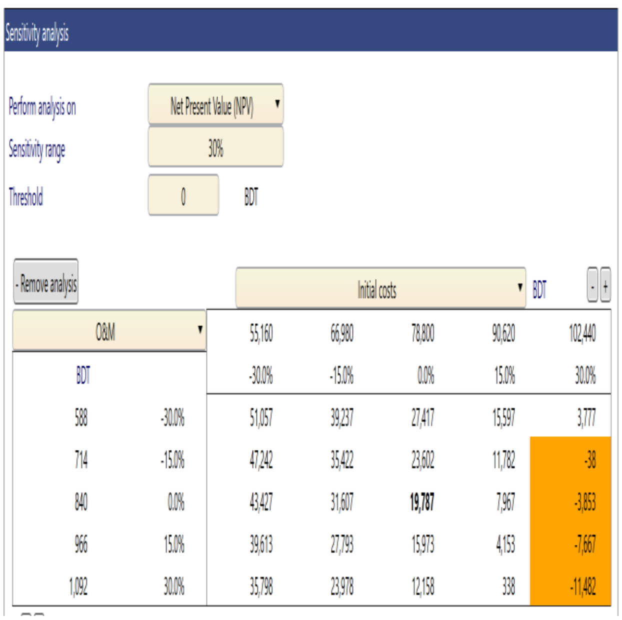


Figure 3:Cumulative cash flow graph of the project

C. Sensitivity Analysis

The uncertainty associated with various inputs of this project may affect the indicators offinancial viability [12]. The RETScreen software allows the user to see how variation in two input parameters affects an indicator of financial viability. In this study, the sensitivity analysis was done for the net present value (NPV) of the project by varying the initial cost against operation and maintenance (O&M) cost by ± 30%, as shown in Figure 4.

The current initial cost of the project is 78,800 BDT; with a 30% increase, the cost will be 102,440 BDT, and with a 30% decrease, the cost will be 55,160 BDT. Also, the current operation and maintenance (O&M) cost is 840 BDT, with a ± 30%, it will be 1,092 BDT and 588 BDT, respectively. The software will provide different NPV for a different combination of initial cost and O&M cost holding all other parameters fixed. The software also indicates the values of the NPV below the threshold of zero by orange color. From Figure. 4, it can be concluded that the initial cost is far more sensitive than the operation and maintenance cost. A 30% increase in the initial cost cannot be compensated with a 15% decrease in O&M cost.



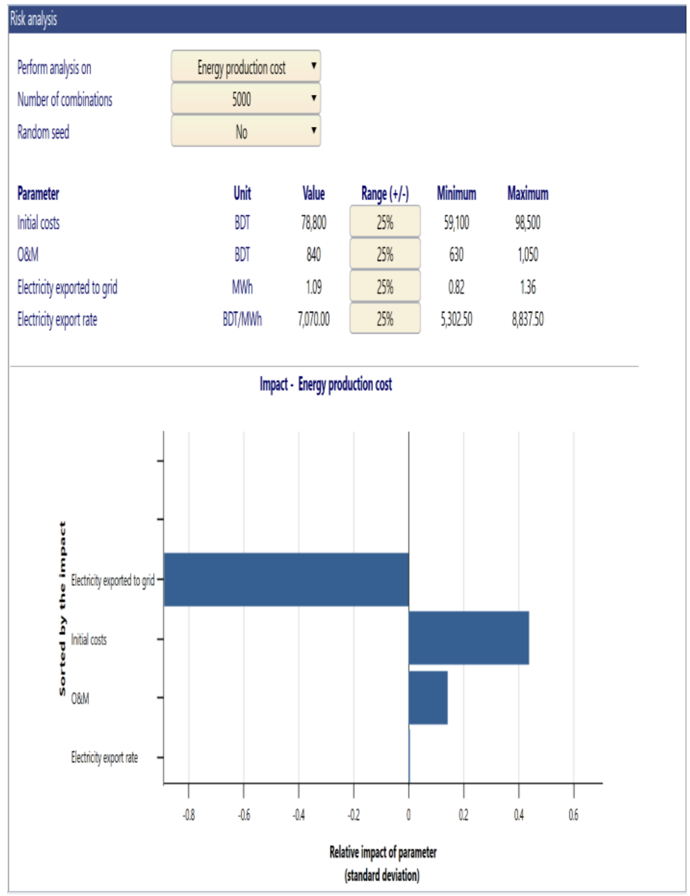
O&M (BDT)		55,160 (-30.0%)	66,980 (-15.0%)	78,800 (0.0%)	90,620 (15.0%)	102,440 (30.0%)
588	-30.0%	51,057	39,237	27,417	15,597	3,777
714	-15.0%	47,242	35,422	23,602	11,782	-38
840	0.0%	43,427	31,607	**19,787**	7,967	-3,853
966	15.0%	39,613	27,793	15,973	4,153	-7,667
1,092	30.0%	35,798	23,978	12,158	338	-11,482

Figure 4: Sensitivity analysis result for the renewable energy-based security system.

D. Risk Analysis

Risk analysis determines the impact of different input parameters on a financial indicator by allowing the parameters to vary with each other within a specific range during the analysis. The energy production cost is selected as a financial indicator, and the range is considered ± 25% for all the parameters. The RETScreen performed a Monte Carlo Simulation 5000 times to recalculate the energy production cost considering the changes in input parameters.

The impact graph, as shown in Figure 5, displays the impact of different parameters on the energy production cost. According to the graph, the electricity exported to the grid and the initial cost have the biggest impact on the energy production cost, although their influences are opposite in sign. An increase in the initial cost increases the energy production cost, whereas an increase in the electricity exported to the grid decreases the energy production cost.



Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	BDT	78,800	25%	59,100	98,500
O&M	BDT	840	25%	630	1,050
Electricity exported to grid	MWh	1.09	25%	0.82	1.36
Electricity export rate	BDT/MWh	7,070.00	25%	5,302.50	8,837.50

Figure 5: Impact graph of the risk analysis

E. Emission Analysis

Emission analysis determines the amount of greenhouse gas (GHG) emission reduction through the implementation of the solar PV system. In Bangladesh, maximum power plants use natural gas to produce electricity. In this study, natural gas is considered a fuel type for grid electricity. The transmission and distribution (T&D) losses of 11% [13] and GHG emission factor of 0.537 tCO^2/MWH (RETScreen Expert database) were considered as the base case electricity system in Bangladesh. The project can produce 1.1 MWh of electricity per year which in turn, can reduce the emission of 600 kg of CO2 per year.

VI. CONCLUSION

Solar energy is the most abundant renewable energy source in Bangladesh. This study aims to promote the versatile use of renewable energy in different fields. Security cameras require 24 hours of non-stop power to operate, but the grid can not provide 24 hours of non-stop electricity because of load-shedding. In that case, a solar PV system would be a great substitute for grid electricity; the user can operate solar-based security cameras without the fear of being power cut. Implementation of a solar power-operated project is costly, so before carrying out any renewable energy-based project, one must conduct a feasibility analysis to evaluate the financial and environmental viability. The feasibility analysis of our project indicates that the renewable energy-based surveillance system is financially feasible in terms of the net present value (NPV), internal rate of return (IRR), annual life cycle savings, and benefit-cost (B-C) ratio.

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