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Feasibility of Grid-Tied Rooftop Solar System Installation at Khwaja Yunus Ali University (KYAU), Bangladesh

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Abstract

This paper aims to design an implementable solution to save at least 48% electricity per year at Khwaja Yunus Ali University by using grid-tied photovoltaic (PV) solar at its three buildings. The campus of the university is a suitable area to produce rooftop solar energy due to its infrastructure and geological characteristics. This paper demonstrates how to make an educational institution into an educational green energy campus like many educational institutions in western countries. By the installation of the designed grid-tied solar on its building's rooftop, the KYAU can produce more than 750MWh energy per year. If the authority of KYAU accepts this design for implementation, then the university will be the first green energy campus in Bangladesh

Keywords: Grid-Tied, Rooftop Solar, Environment Friendly, Green Campus, Software simulation

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Introduction

There is a huge potential of solar energy. It is very crucial to save the world from the high temperature that the total energy needs of the whole world can be fulfilled by the solar energy (Karim et al. 2016). The total energy consumption of the whole world in the year 2013 was 567exajoule (1EJ=1018 J) or approximately 157.5PWh (1.575×1017Wh). Almost 80%-90% of this energy came from fossil fuel (Karim et al. 2016). From the sun earth receives 3,850,000 EJ of energy, which is equivalent to 174 pita watts (1 PW=1015 W) (Sharma et al. 2014). The earth does not hold all the energy, a part of it reflects back. After reflection earth receives 89 PW of energy. However, only less than 0.02% is enough to replace the fossil fuel and nuclear power supply in the whole world at present. This reflects the great potential of solar energy for the earth. Considering green house effect, other environmental impact, cost, risk and availability solar energy has the greatest potential among all the energy sources (Karim et al. 2016).

According to Doug Pearce (2010/11), the photovoltaic effect, or the conversion of sunlight into electricity, was first discovered in 1839 (Alyssa 2016a). Just over 100 years later in 1941 the first solar cell was invented. By the early sixties, satellites were being powered by solar panels, albeit very expensive. Although commercially available since the seventies, solar panels were prohibitively expensive (around $100 per watt) and as such found use mainly in remote area power supplies where grid connection was not available. By the early 1990s efficiencies were improving, but cost was still a major issue. With the advent of concerns over global warming research into solar panel, technologies have accelerated and in February 2009, the first Solar became the first manufacturer to produce a panel for less than $1 per watt. Solar is now a financially viable alternative power source and with continuing development of existing and new technologies will become even more so (Doug, 2010/11).

Literature review

What is Solar Energy?

Everyday, the sun radiates (sends out) an enormous amount of energy—called solar energy (NEED Project, 2017). It radiates more energy in one day than the world uses in a year. This energy comes from within the sun itself. Like most stars, the sun is a big gas ball made up mostly of hydrogen and helium gas. The sun makes energy in its inner core in a process called nuclear fusion. It takes the sun's energy just a little over eight minutes to travel the 93 million miles to Earth. Solar energy travels at the speed of light, or 186,000 miles per second, or 3.0 x 108 meters per second. Only a small part of the visible radiant energy (light) that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy needs. Every hour enough solar energy reaches the Earth to supply its energy needs for a year! Solar energy is considered a renewable energy source due to this fact. Today, people use solar energy to heat buildings, water and generate electricity. Solar energy is mostly used by residences and to generate electricity.

Why solar energy needed?

Using solar energy in Bangladesh

According to Chattopadhyay et al. (2015), millions of Bangladeshi families have benefited in terms of quality of service and the various social and economic benefits brought from the ability to have household lighting. The program was well designed on three counts, namely: (1) it was crafted around a pre-existing strong microfinance infrastructure; (2) it had a strong emphasis on quality assurance; and (3) it also placed a strong emphasis on customer confidence-building process. This program has been instrumental in creating thousands of additional jobs and a 9.3% increase in food expenditure as villagers have more productive time that they could invest in other activities (Zubair et al., 2014). More generally, a combination of dramatic PV price declines, coupled with improved DC-based appliances, improved lighting technologies (such as LEDs), and innovative financing and business models have created a more attractive environment for SHS. In other words, the systems can now provide a set of much better services in terms of quantity and quality. As noted, in addition to Bangladesh, there is a vast range of small- to large-scale SHS programs in other parts of Asia (including India and China), Africa, and Latin America. The REN 21 Renewable 2014 Global Status Report noted that Argentina, Bangladesh, China, India, Sri Lanka, Indonesia, Mongolia, and Vietnam, are among the most successful countries in terms of the number of SHS and other solar kits delivered (Renewable, 2014).

Solar energy using universities

According to Alyssa (2016b), there are 10 universities are not only working to make their students smarter but also to make their campuses smarter by using solar energy and empowering their students and staff to do the same. The universities are 1. Northwestern University, 2. Drexel University, 3. University of Arizona, 4. Butte College, 5. University at Buffalo, 6. Colorado State University, 7. Princeton University, 8. University of Tennessee, Knoxville, 9. The University of Utah, and 10. Santa Clara University.

Universities around the world are installing solar panels as part of a quest to reduce carbon emissions, reduce energy costs, provide research opportunities and be seen as good corporate citizens (Hasapis et al. 2017). Pondicherry University, India and the University of Western Australia had also set up rooftop grid-tied solar on its buildings and use solar energy at varies activities (Sanjoy et al. 2017). In Bangladesh, the BRAC University has initiated to install a small size solar system on its rooftop. Bangladesh has recently been able to see its First Ever Solar Power Plant with a capacity of 3 MW. From 3rd August'17, this Large-scale Solar Power Plant started supplying power to the National Grid, which is for the first time in the country's history; evacuating power to the nearby BPDB-owned Jamalpur Sarishabari 33/11 kV Sub-station (Islam, et al. 2018). The campus of Khwaja Yunus Ali University is a suitable area for producing rooftop solar energy due to its infrastructure and geological characteristics. By the installation of the designed grid-tied solar on its building's rooftop, the KYAU can produce more than 750MWh energy per year.

Khwaja Yunus Ali University

The University and its present energy situation

Khwaja Yunus Ali University (KYAU), one of the leading private Universities in Bangladesh, was founded in 2012 under the Private University Act 2010 with a vision to create a higher education Centre of excellence and named after Sufi saint Khwaja Yunus Ali (R). It is situated in Sirajgonj, Rajshahi. KYAU offers students from all walks of life the advantages of an affordable customized education of global standard as a modern, dynamic and creative institution for undergraduate and graduate students. KYAU lays stress on quality education to be at par with an exponential increase in Twenty-first Century technological development, to make the participants a workforce to meet the needs of 21st Century. The university is enjoying 24 hours electricity supply because of its dynamo system and grid utility. In 2017, the energy consumption of KYAU is 1, 01,414 kWh, which is 15% more the previous year.

Energy demand of this university

The energy demand of KYAU is increasing day by day. At the end of the year 2019, the energy demand of KYAU will reach at 200MWh/Year. In 2020, KYAU needs more than 400MWh/Year. In this regard, some energy consumable labs like Mechanical lab, Machine lab, High voltage and switchgear lab, Microwave and telecommunication lab, Computer and simulation lab will be run at full face. Moroever, in 2024, the Khwaja Yunus Ali University will need more than 750MWh per year when it will celebrate its first decade anniversary.

Methodology

Survey

Load Survey

Finding out and understanding the total energy consumption of KYAU is the first step in designing an Energy Program for KYAU (Lashway et al. 2014). In this part, it was observed the data of energy consumption figures and facts of KYAU. The peak and off-peak data were collected and analysed the monthly load from January to December 2017. Annual electrical energy consumption of KYAU was 1, 01,414 kWh. The total off-peak (12 am to 5 pm) energy consumption is 83,744 kWh and the peak energy (6pm to 11pm) consumption is 17,670 kWh. Average energy monthly consumption including off-peak and peak is 8,451 kWh. In 2017, KYAU's authority pays total 13729 USD against 101414 units electricity, hence, per unit electricity bill is 0.1354 USD[1].

Table 1: KYAU monthly electricity bill, 2017

Months	Grid Supply (Kwh)		Dynamo supply (Kwh)		Total (Kwh)		
	Off peak hour	Peak hour	Off peak hour	Peak hour	Off peak hour	Peak hour	Total
January	5330	1066	90	16	5420	1082	6502
February	3526	705	250	56	3776	761	4537
March	3362	672	1520	450	4882	1122	6004
April	6068	1213	821	164	6889	1377	8266
May	6560	1320	1837	404	8397	1724	10121
June	6642	1370	520	120	7162	1490	8652
July	3772	943	4793	1998	8565	2941	11506
August	7216	1295	950	190	8166	1485	9651
September	7298	1420	440	88	7738	1508	9246
October	9512	1630	659	104	10171	1734	11905
November	6150	1189	450	96	6600	1285	7885
December	5412	1026	566	135	5978	1161	7139
Total	70848	13849	12896	3821	83744	17670	101414

Site Survey

Khwaja Yunus Ali University has three buildings, which include Academic Building, Departmental New Building and Student's Hall. Thus, there is enough roof space to install a PV system for supplying electricity to the building. The rooftops of KYAU campus are not used for useful purposes, therefore, these are available for use. Installation PV modules at the rooftop will have an additional advantage of reducing the heat gain of the building from the top. In the case of rooftop connected PV systems, the electricity demands of the building are met by the PV system and only the excess is fed into the grid. But during the unsuitable atmospheric conditions, when the load demand is not met by the PV generation, at that instant the required energy can be taken out from the utility grid. The building's roof or orientation depends on solar radiation directly. The design of the solar PV array layout is planned diligently to avoid presently possible shadow from the water tanks, sidewalls, columns and nearby buildings. Rows of the arrays are laid in such a way that there is no shadow from one row to another. A simple rule for minimum spacing between rows is to allow a space equal to three times the height of the top of the row or obstruction in front of an array (Sanjoy et al.

[1]Accounts office, KYAU

2017). For these reasons, we considered 45-50% of the total area. So finally excluding those 45-50% areas; we get a total rooftop area for grid-tied solar design and simulation. Figure 3 shows a side view of KYAU campus.

Table 2: Measurement of usable area

Buildings	Actual Rooftop Area	Designable Rooftop area (m^2)
Academic Building	16900 square feet or 1570 square meter	805
Departmental Building	29780 square feet or 2766 square meter	1410
Student's Hall	11700 square feet or 1087 square meter	505
Total	58380 square feet or 5423 square meter	2720

The total area of roof top can be presented in above table. So, the total usable area 2720 square meter.

Irradiance of the site

Irradiance means the amount of electromagnetic energy incident on the surface per unit time per unit area. Hence, the total solar irradiation is defined as the amount of radiant energy emitted by the sun over all wavelengths that fall each second on $1m^2$($11\ ft^2$) outside earth's atmosphere. We can easily calculate Irradiance of a site by using the following formula

$$\text{Irradiance} = \frac{Average Insolation}{Average daily bright sunshine hours} \, {}^{KWh}/_{m^2}$$

It is very important to know the irradiation and insulation of a site when anyone is going to design a solar PV system for that site. Depending on the sunshine, irradiance and insulation process varies with a place to place. The irradiance of the Enayetpur, Sirajgonj can be calculated from Tables 3 and 4.

Table III: Monthly global solar insulation in Enayetpur, Sirajgonj, Bangladesh

Month	Solar insolation, ${}^{KWh}/_{m^2}$
January	4.34
February	5.07
March	5.87
April	6.05
May	5.51
June	4.74
July	4.26
August	4.30
September	3.91
October	4.36
November	4.39
December	4.17
Average	4.74

Table IV: Daily average bright sunshine hours in Enayetpur, Sirajgonj, Bangladesh

Month	Daily mean	Minimum	Maximum
January	7.91	6.83	9.01
February	8.28	7.01	9.74
March	8.01	6.83	9.19
April	8.10	7.10	9.28
May	7.46	5.19	8.83
June	4.45	3.46	6.64
July	4.64	2.37	6.10
August	5.27	3.73	6.46
September	5.46	4.37	7.74
October	6.91	5.92	8.37
November	7.82	6.37	9.01
December	8.10	6.73	9.28
Average	6.89	5.49	8.30

The daily average bright sunshine hours in Enayetpur, Sirajgonj is 6.89hours and the average solar insulation is 4.74 kWh/ m^2. From formula, we get the irradiance of Enayetpur, Sirajgonj is 687.95 watt/m^2. This value will be used for KYAU solar PV system design.

Selection

Rooftop Solar System Configuration

There are many possible configurations of a solar PV system. Each of these configurations has its own advantages and disadvantages. Depending on the system requirements appropriate system configurations has to be chosen. In our work, at first, we considered two possible configurations for KYAU campus. The first one is grid-connected solar PV system without battery, which is called Grid Tied system (Figure 1) and the second one is stand-alone solar PV system with battery (Figure 2).

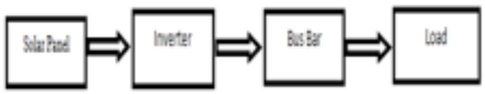


Figure 1: Grid Tied PV system without Battery (Proposed configuration for KYA University).

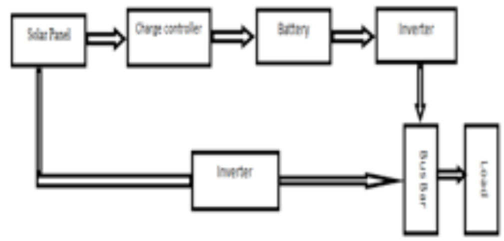


Figure 2: Stand alone solar PV system with Battery.

The block diagram shows the design configuration where the solar panels will be connected to inverters, then from the inverter current will be supplied to the university's bus bar then to the load. The proposed grid-tied system without battery can't supply electricity if the utility grid is disconnected during the night or on a rainy day when sunlight is not sufficient.

The block diagram shows a design configuration that can both supply and store energy. When the demand is high then the system will deliver energy same as figure 4 as described. But when the demand is low or in an off day the battery can store energy by solar panel through a charge controller. This stored energy can be used as a backup for a gloomy day or at night.

Due to the cost-effective, reliable and environmentally friendly system, we select the grid-tied PV system without battery, figure 1, for KYAU.

Figure 3: Campus of Khwaja Yunus Ali University

Selecting the PV module
The different panel technologies have been ranked according to their suitability for installation at the KYAU campus. The following criteria have been considered:

- Cost per watt
- Watts per square meter (efficiency)
- Appearance
- Degradation rate
- Reliability
- Durability
- Technology Maturity
- Temperature output decrease

Considering the above factors, we have selected a module of Solar World brand. Figure 4 shows the solar module and the model is Sun module SW 300 mono. Its maximum output power is 300 watt, if irradiance is 1000 watts per Meter Square. Then the module's nominal power output is 226.7 watt if irradiance is 800 watts per Meter Square. The irradiance of Enayetpur, Sirajgonj is 687.95 W/m2. So we will get power, approximately 216watts. 25 years power output warranty is 90%. The panel efficiency is 17.89%. Short circuit current of the panel is 9.83A at standard test condition and 8.06A at the nominal condition. Figure 5 shows the dimensions of the panel are length 1675mm, width 1001mm and height 33mm.

Figure 4: SW 300 mono module

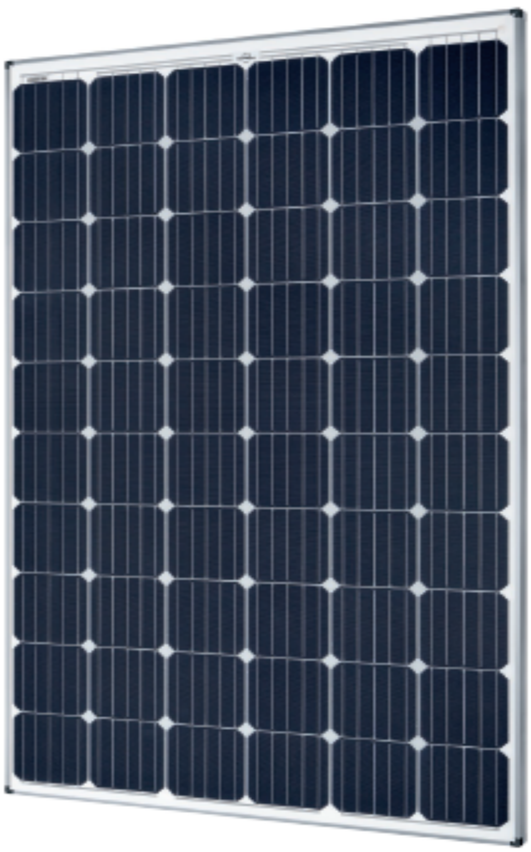
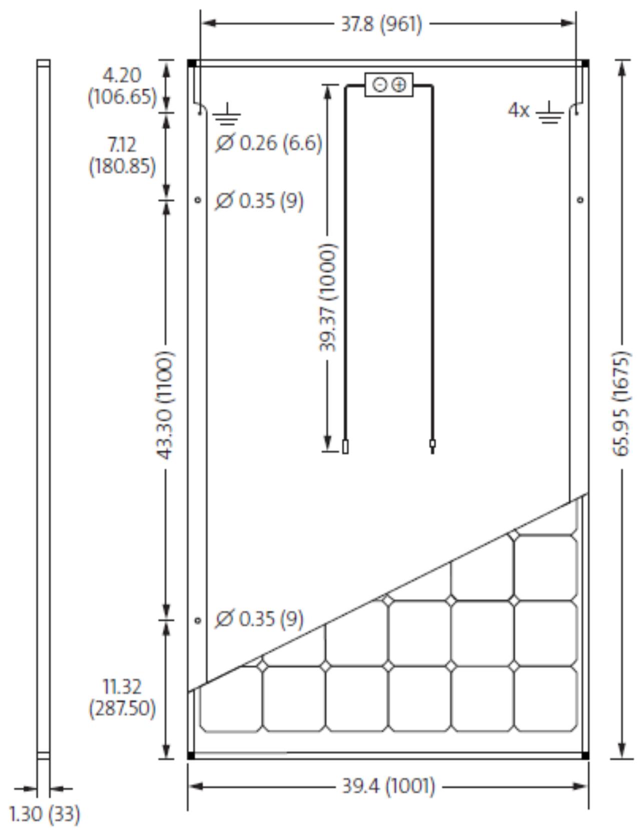


Figure 5: SW 300 mono module's dimension diagram



Selecting the Inverter
AE 3TL 17(867) 17KW Inverter: We selected a PV grid-tied inverter. The model is AE 3TL 17(867) 17KW. It is a product of Advanced Energy. The AE 3TL is designed with many different applications in mind. These high-quality inverters can be used for commercial rooftop and carports installations to solar power plants. With a power range of 12 to 23.2 kilowatts, the AE 3TL is situated to serve installations large and small. The AE 3TL optimize space in the site design, allowing for placement with the array, saving site owners highly valued space. Highly precise MPP tracking combined with AE solar energy's advanced monitoring solution gives solar stockholders the vital data needed to operate and maintain a highly efficient site, providing maximum returns for an investor in solar energy. AE solar energy listens carefully to customer demands. The AE is lightweight and easy to install. Weighing just over 100 pounds, the easily installed inverter is very well suited for rooftop or space-constrained installations and decreases initial system costs for the project below 400KW. Arrays designed with the AE 3TL string inverters have best-in-class uptime, system yields and problem resolution.

Figure 6: AE 3TL 17(867) 17KW grid tied Inverter

Fig. 2: External dimensions

- Voltage range: 460 - 850 V
- Output power: 17kW
- Maximum DC input current: 38.3 A
- Connection: 50Hz grid frequency and 3 phase 4 wire connection
- The efficiency of this inverter: 98.2%.
- AC voltage: 320 - 460Volts.

VC WL 280 250KW Inverter: We selected another type of inverter for Departmental new building of Khwaja Yunus Ali University which model is VC WL 280. It is a 250KW inverter, which main features are mansion here:

- The MPPT voltage range: 450- 800 V
- Output power: 250 KW
- Maximum DC input current: 400 A.
- Connection: 50Hz grid frequency and 3 phase 4 wire connection
- The efficiency of this inverter: 98.2%.
- AC voltage: 230 Volt.

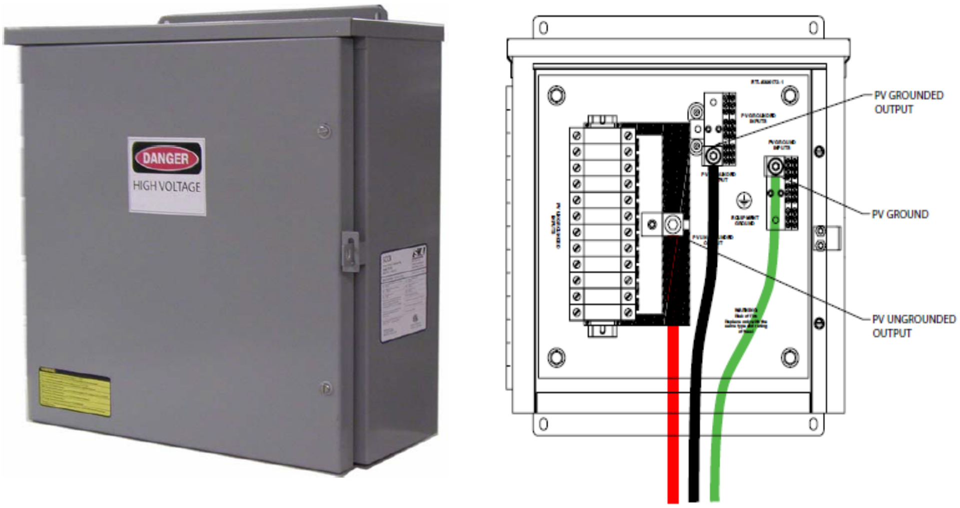
Figure 7: VC WL 280 250KW Inverter

Selecting Combiner Box

SMA SCCB-12 Combiner Box: The Combiner Boxes are designed and tested according to international safety requirements, but as with all electrical and electronic equipment, certain precautions must be observed when installing the Combiner Boxes. To reduce the risk of personal injury and to ensure the safe installation and operation of the Combiner Boxes, we select a best combiner box. The model of selected combiner box is SMA SCCB-12. The special features of the SMA combiner box are:

- The no of input circuit: 12
- Maximum input fuse rating: 24 A, 600V DC
- Maximum output current: 240 A DC

Figure 8: The SMA SCCB-12 combiner box and its connection diagram



SMA SCCB-52 Combiner Box: The SCCB 52, 52 Circuit Sunny Boy Combiner Box provides greater flexibility and expandability in system design. Oversized bus-work adds high efficiency and dependability where it's needed most. The large NEMA 3R enclosure provides ample room for conductors which reduces installation time. Designed with
installers in mind, SMA America knows you'll find the new SCCB Combiner Boxes a welcome addition to a great line of inverter products.

Features:

- Greatly simplifies input and output wiring
- 52 circuit, 416 A, 600VDC
- Compact, rugged low cost design

- Reliable bus-work for efficient high current conductor combining
- PV positive wires all land directly on Touch Safe™ fuse holders
- Sturdy NEMA 3R wall mount steel enclosure
- ETL Listed to UL 1741.

Selecting the mounting structure

There are various types of mounting of solar panel can be done. Depending on the location and system several types of mounting is done. We have to construct a mounting rooftop structure for setting up our modules. We want to purchase the material for mounting to reduce cost from a local market. In the local market, each selected module needs a minimum 300 USD for mounting.

Selecting the wire

Rated short circuit current is 8.18A from the PV module. If there is an effect of higher insulation and lower temperature access current can flow. To prevent these to happen the safety factor is considered. Average insulation at Enayetpur, Sirajgonj is 687.95 W/m2. Therefore maximum short circuit current will be 7.04A. For 3 parallel string, it will be (3×7.04) 21.12A. Considering 30% safety factor, a maximum current rating is 27.45A. Therefore, we have finally chosen 30A rating wiring (wire size 10 AWG) for the academic building and student's Hall of KYAU. For 42 parallel string, it will be (42×7.04) 295.68A. Considering 30% safety factor, the maximum current rating is 380A. So, we also have chosen 380A rating wiring (wire size 500 AWG) for the Departmental new building of KYAU.

Design of the system

PV array design

***Academic building and student's Hall*: **The AE 3TL 17(867) 17kW inverter's MPPT voltage range is 460 -850 V and SW 300 Mono module's open circuit voltage is 40 V. so we can use 20 modules in series (40×20) to produce 800V, which is within the inverter's MPPT voltage range. We didn't put more modules due to safety. Secondly, our selected module's maximum power voltage is 32.6V, which is in the selected inverter's MPPT voltage range: (460 -850V)/20 = (23 – 42.5V). So finally we selected 20 modules in series for each string. The AE 3TL 17(867) 17kW inverter's rated voltage is 620V, so the inverter's maximum rated current is (17000/620) 27.42A. At 687.95W/m^2 our selected SW 300 mono module's short circuit current is 7.04A. If we put 3 parallel string (1 string consist of 20 series module), we get (3×7.04) 21.12A. We cannot put more string, because if there raise a weather condition with low temperature and high insolation excessive current can flow. For safety considering 30% excessive current is 27.45A, which is equal to the inverter's capacity. So finally we selected 3 parallel strings. SMA SCCB-12 combiner box maximum input fuse rating = 600 V, 24A. This is also can withstand 3 parallel strings each consist of 20 series modules. Therefore, our chosen PV array design is 3 parallel strings each consist of 20 series modules for 1 combiner box and 1 inverter.

***Departmental new building*: **The VC WL 280 250KW Inverter MPPT voltage range is 450-800 V and SW 300 Mono module's open circuit voltage is 40 V. so we can use 20 module in series (40×20) to produce 800V, which is within the inverter's MPPT voltage range. We didn't put more modules due to safety. Secondly, our selected module's maximum power voltage is 32.6V, which is in the selected inverter's MPPT voltage range: (450 -800V)/20 = (22.5 – 40V). So finally we selected 20 modules in series for each string. The VC WL 280 250KW inverter's rated voltage is 620V, so the inverter's maximum rated current is (250000/620) 400A. At 687.95W/m^2 our selected SW 300 mono module's short circuit current is 7.04A. If we put 42 parallel string (1 string consist of 20 series module), we get (42×7.04) 295.68A. We cannot put more string, because if there raise a weather condition with low temperature and high insulation excessive current can flow. For safety considering 30% excessive current is 385A, which is equal to the inverter's capacity. So finally we selected 42 parallel strings. SMA SCCB-52 combiner box maximum input fuse rating = 600 V, 414A. This is also can withstand 42 parallel strings each consist of 20 series modules. Therefore, our chosen PV array design is 42 parallel strings each consist of 20 series modules for 1 combiner box and 1 inverter.

Number of module selection, Inverter, Combiner box

Number of module accommodation $=\frac{Total usable area}{Area of a slected PV module}$.

For SW 300 mono module needs (1675mm×1001mm) 1.67668 m^2 areas.

Table 5: Number of selected module, Inviter & Combiner Box

Panel installation location	Usable area (m^2)	Module		Inverter		Combiner Box	
		Number	model	Number	model	Number	model
Academic Building	805	480	SW 300 mono	08	AE 3TL 17(867) 17KW	08	SMA SCCB-10
Departmental New Building	1410	840	SW 300 mono	01	VC WL 280 250KW	01	SMA SCCB-52
Student's Hall	505	300	SW 300 mono	05	AE 3TL 17(867) 17KW	05	SMA SCCB-10
Total	2720	1620		14		14	

Energy Supply

20 PV modules in series in a string and there are two types of configuration. Number one configuration is in 3 strings for academic building and student's Hall, number two configuration is in 42 strings for departmental new building. For our system there would be total 14 configurations. The solar irradiance in Enayetpur, Sirajgonj is 687.95watt/day. The energy supplied by the solar PV system in a year can be found by the following formula.

Total energy supply from Academic building of KYAU's rooftop solar = Maximum Power at defined irradiance of a solar panel$\times$ Average bright sunshine hour $\times 365$ days $\times$number of solar panels =$(212\times 6.89\times 365 \times 480)$ $Wh/Year$= 255911136$Wh/Year$ = 255.91$MWh/Year$. Considering 90% of panel's output efficiency the total energy supply = 230.32$MWh/year$.

Similarly, Total energy supply from Departmental building of KYAU's rooftop solar = 403.06$MWh/year$.

Total energy supply from Student's Hall of KYAU's rooftop solar = 143.95$MWh/year$.

Grand total energy supply from KYAU's rooftop solar = 777.33$MWh/year$.

Cost Calculation of the system

Cost calculation

To implement the proposed solar PV system for KYAU campus, we need to have a clear concept on the implementation cost. In these consequences, we have calculated the approximation cost in USD. Table VI, VII & VIII shows all the components that we have required implementing a solar PV system for three separate building of KYAU. These components are PV modules, inverters, combiner boxes, and surge arrestors, lightning rod, mounting, meters, wiring. We also have to consider the transportation, installation, LC and maintenance costs. We have considered this as the 40% of all components costs.

Table 6: Approximate cost calculation for Academic Building of KYAU's rooftop solar

Component	Description	Quantity	Cost
PV Module	SW 300 mono	480	182000 USD
Inverter	AE 3TL 17(867) 17KW	8	49440 USD
Combiner Box	SMA SCCB-10	8	9280 USD
Surge Arrester		1	200 USD
Lighting Rod		2	120 USD
Mounting Structure	From Local market	480	14400 USD
Meter	3 phase energy meter	1	60 USD
Wiring	30 A wire		500 USD
	Total Materials Cost:		256000 USD
Transportation, installation, LC and maintenance	40% of all cost		102400 USD
Project plan and Engineering			300 USD
VAT (15%)			38400 USD
Annuities (8%)			20480 USD
Total cost			417580 USD

Table 7: Approximate cost calculation for Departmental New Building of KYAU's rooftop solar

Component	Description	Quantity	Cost
PV Module	SW 300 mono	840	319200 USD
Inverter	VC WL 280 250KW	1	12180 USD
Combiner Box	SMA SCCB-52	1	1600 USD
Surge Arrester		2	400 USD
Lighting Rod		4	240 USD
Mounting Structure	From local market	840	25200 USD
Meter	3 phase energy meter		60 USD
Wiring	300 A wire		900 USD
	Total Material Cost:		359780 USD
Transportation, installation, LC and maintenance	40% of all cost		143912 USD
Project plan and Engineering			300 USD
VAT (15%)			53967 USD
Annuities (8%)			28783 USD
Total cost			586742 USD

Table 8: Approximate cost calculation for Student's Hall of KYAU's rooftop solar

Component	Description	Quantity	Cost
PV Module	SW 300 mono	300	114000 USD
Inverter	AE 3TL 17(867) 17KW	5	30900 USD
Combiner Box	SMA SCCB-12	5	5800 USD
Surge Arrester		1	200 USD
Lighting Rod		2	120 USD
Mounting Structure	From local market	300	9000 USD
Meter	3 phase energy meter	1	60 USD
Wiring	30 A wire		500 USD
	Total material cost:		160580 USD
Transportation, installation, LC and maintenance	40% of all cost		64232 USD
Project Plan and Engineering			300 USD
VAT (15%)			24087 USD
Annuities (8%)			12847 USD
Total cost			262046 USD

After doing calculation the total cost stands around 1266368USD.

Per unit energy cost of grid tied solar system

We consider our proposed PV system life is 25 years. So, the cost per unit of energy by the designed system will be:

Total cost of the system: 1266368 USD (from table VI, VII & VIII)

Energy production rate is 777.33$MWh/year$

Energy production in 25 year = 777.33×25 ×1000 = 19433250 KWh

Cost per unit of energy in USD: (Total cost of the system/ Energy Produced in 25 years)

= (1266368/19433250)

= 0.0652

So we could be able to generate per unit of energy at 0.0652 USD or (0.0652×80) TK

= 5.16 Taka

Profit and Payback return

Table IX: Payback Time calculation of the solar system (Al-Ammar *et. al*. 2010)

S.N	Topics	Formula	U.S Dollar	Bangladeshi Taka
1	Total cost of the system		1266368 USD	Tk. 101309440
2	Per year costing (Life time 25 year)	1/25	50655 USD	Tk. 4052378
3	Total Energy production in 25 year		19433250 KWh	19433250 KWh
4	Per year energy production	3/25	777330 KWh	777330 KWh
5	Per KWh energy prize		0.1354 USD	Tk. 10.83
6	Total Energy prize in 25 year	3×5	2631262 USD	Tk. 210462098
7	Per year energy prize	6/25	105250 USD	Tk. 8418484
8	Net saving per year	7-2	54595 USD	Tk. 4366106
9	Payback period with Electricity Bill	1/7	12.03 Year	12.03 Year
10	Payback period without Electricity Bill	1/8	23.20 Year	23.20 Year

Simulation Design

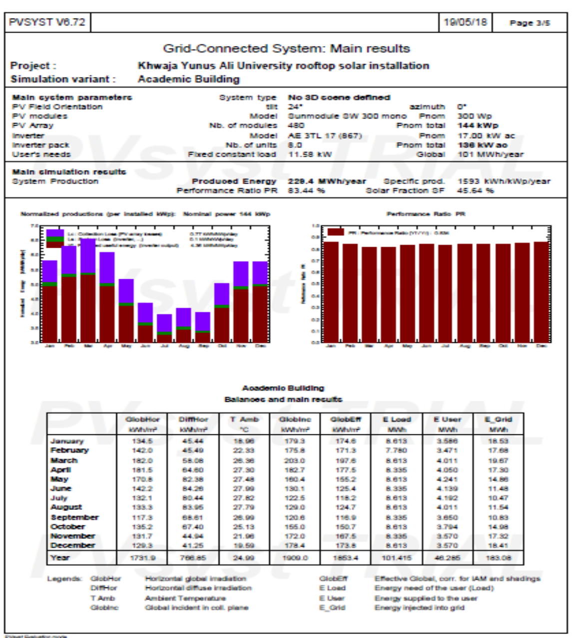
PVSYST Software for simulation

For the PV system designed for KYAU campus, we have chosen for simulation is PVSYST software. PVSYST has several built-in mathematical models for a component such as a photovoltaic module, inverter and other tools. PVSYST gives two types of designing options as preliminary design and project design. Using these options there are various kinds of system can be developed. We chose the project design option. There are many options to define parameters for designing a project of different types of systems like grid connected /standalone /dc grid connected/pumping. In this case, we chose a grid-connected option. To design such types of systems, this section has different steps such as location, horizon and system sizing. To construct a system, there are many components like module and inverter choosing, sizing array which shows a number of the modules connected in series and parallel etc. PVSYST makes the users interconnect this component to develop a virtual PV system and simulates that. After simulation, users get the simulation result. By using the PVSYST software, we have developed one.

Simulation Result

We perform three simulations for every separate building of Khwaja Yunus Ali University and mention here separately in the name of simulation result I, II &III and finally we cumulative them to analysis with theoretical result. The total simulation result of PVSYST software has been comes out 770.90MWh/year.

Simulation Result 1: Academic Building Simulation



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Grid-Connected System: Main results

Project : Khwaja Yunus Ali University rooftop solar installation
Simulation variant : Academic Building

Main system parameters — System type: No 3D scene defined
PV Field Orientation — tilt 24° — azimuth 0°
PV modules — Model Sunmodule SW 300 mono — Pnom 300 Wp
PV Array — Nb. of modules 480 — Pnom total 144 kWp
Inverter — Model AE 3TL 17 (867) — Pnom 17.00 kW ac
Inverter pack — Nb. of units 8.0 — Pnom total 136 kW ac
User's needs — Fixed constant load 11.58 kW — Global 101 MWh/year

Main simulation results
System Production — Produced Energy 229.4 MWh/year — Specific prod. 1593 kWh/kWp/year
Performance Ratio PR 83.44 % — Solar Fraction SF 45.64 %

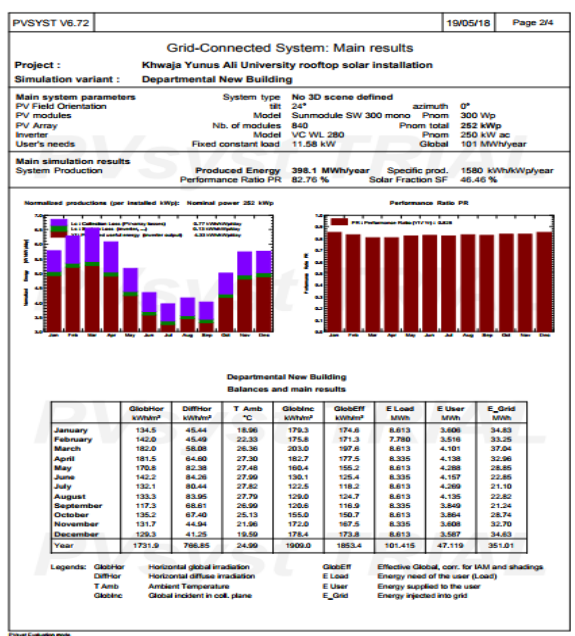
Academic Building
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	E Load MWh	E User MWh	E_Grid MWh
January	134.5	45.44	18.96	179.3	174.6	8.613	3.586	18.53
February	142.0	45.49	22.33	175.8	171.3	7.780	3.471	17.68
March	182.0	58.08	26.36	203.0	197.6	8.613	4.011	19.67
April	181.5	64.60	27.30	182.7	177.5	8.335	4.050	17.30
May	170.8	82.38	27.48	160.4	155.2	8.613	4.241	14.86
June	142.2	84.26	27.99	130.1	125.4	8.335	4.139	11.48
July	132.1	80.44	27.82	122.5	118.2	8.613	4.192	10.47
August	133.3	83.95	27.79	129.0	124.7	8.613	4.011	11.54
September	117.3	68.61	26.99	120.6	116.9	8.335	3.650	10.83
October	135.2	67.40	25.13	155.0	150.7	8.613	3.794	14.98
November	131.7	44.94	21.96	172.0	167.5	8.335	3.570	17.32
December	129.3	41.25	19.59	178.4	173.8	8.613	3.570	18.41
Year	1731.9	766.85	24.99	1909.0	1853.4	101.415	46.285	183.08

Legends: GlobHor Horizontal global irradiation; DiffHor Horizontal diffuse irradiation; T Amb Ambient Temperature; GlobInc Global incident in coll. plane; GlobEff Effective Global, corr. for IAM and shadings; E Load Energy need of the user (Load); E User Energy supplied to the user; E_Grid Energy injected into grid

PVsyst Evaluation mode

Result 2: Departmental New Building



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Grid-Connected System: Main results

Project : Khwaja Yunus Ali University rooftop solar installation
Simulation variant : Departmental New Building

Main system parameters — System type: No 3D scene defined
PV Field Orientation — tilt 24° — azimuth 0°
PV modules — Model Sunmodule SW 300 mono — Pnom 300 Wp
PV Array — Nb. of modules 840 — Pnom total 252 kWp
Inverter — Model VC WL 280 — Pnom 250 kW ac
User's needs — Fixed constant load 11.58 kW — Global 101 MWh/year

Main simulation results
System Production — Produced Energy 398.1 MWh/year — Specific prod. 1580 kWh/kWp/year
Performance Ratio PR 82.76 % — Solar Fraction SF 46.46 %

Departmental New Building
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	E Load MWh	E User MWh	E_Grid MWh
January	134.5	45.44	18.96	179.3	174.6	8.613	3.606	34.83
February	142.0	45.49	22.33	175.8	171.3	7.780	3.516	33.25
March	182.0	58.08	26.36	203.0	197.6	8.613	4.101	37.04
April	181.5	64.60	27.30	182.7	177.5	8.335	4.138	32.96
May	170.8	82.38	27.48	160.4	155.2	8.613	4.288	28.85
June	142.2	84.26	27.99	130.1	125.4	8.335	4.157	22.85
July	132.1	80.44	27.82	122.5	118.2	8.613	4.269	21.10
August	133.3	83.95	27.79	129.0	124.7	8.613	4.135	22.82
September	117.3	68.61	26.99	120.6	116.9	8.335	3.849	21.24
October	135.2	67.40	25.13	155.0	150.7	8.613	3.884	28.74
November	131.7	44.94	21.96	172.0	167.5	8.335	3.608	32.70
December	129.3	41.25	19.59	178.4	173.8	8.613	3.587	34.63
Year	1731.9	766.85	24.99	1909.0	1853.4	101.415	47.119	351.01

Legends: GlobHor Horizontal global irradiation; DiffHor Horizontal diffuse irradiation; T Amb Ambient Temperature; GlobInc Global incident in coll. plane; GlobEff Effective Global, corr. for IAM and shadings; E Load Energy need of the user (Load); E User Energy supplied to the user; E_Grid Energy injected into grid

PVsyst Evaluation mode

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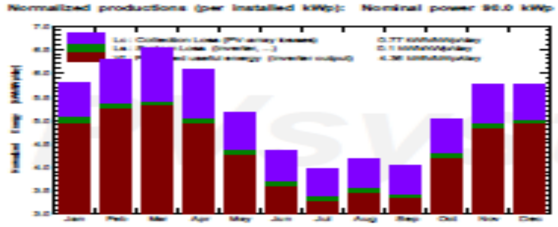
Grid-Connected System: Main results

Project : **Khwaja Yunus Ali University rooftop solar installation**
Simulation variant : **Student's Hall**

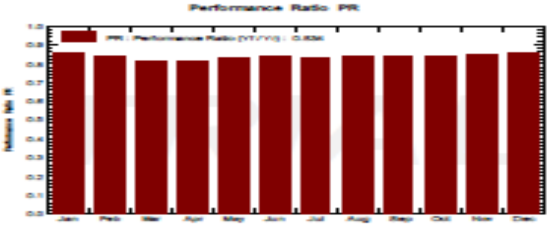
Main system parameters	System type	**No 3D scene defined**		
PV Field Orientation	tilt	24°	azimuth	0°
PV modules	Model	Sunmodule SW 300 mono	Pnom	300 Wp
PV Array	Nb. of modules	300	Pnom total	**90.0 kWp**
Inverter	Model	AE 3TL 17 (867)	Pnom	17.00 kW ac
Inverter pack	Nb. of units	5.0	Pnom total	**85.0 kW ac**
User's needs	Fixed constant load	11.58 kW	Global	101 MWh/year

Main simulation results				
System Production	**Produced Energy**	**143.4 MWh/year**	Specific prod.	1593 kWh/kWp/year
	Performance Ratio PR	83.44 %	Solar Fraction SF	43.45 %

Normalized productions (per installed kWp): Nominal power 90.0 kWp



Performance Ratio PR



Student's Hall
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	E Load MWh	E User MWh	E_Grid MWh
January	134.5	45.44	18.96	179.3	174.6	8.613	3.539	10.28
February	142.0	45.49	22.33	175.8	171.3	7.780	3.389	9.63
March	182.0	58.08	26.36	203.0	197.6	8.613	3.848	10.95
April	181.5	64.60	27.30	182.7	177.5	8.335	3.811	9.53
May	170.8	82.38	27.48	160.4	155.2	8.613	3.984	7.96
June	142.2	84.26	27.99	130.1	125.4	8.335	3.875	5.69
July	132.1	80.44	27.82	122.5	118.2	8.613	3.854	5.31
August	133.3	83.95	27.79	129.0	124.7	8.613	3.741	5.98
September	117.3	68.61	26.99	120.6	116.9	8.335	3.352	5.70
October	135.2	67.40	25.13	155.0	150.7	8.613	3.655	8.08
November	131.7	44.94	21.96	172.0	167.5	8.335	3.486	9.57
December	129.3	41.25	19.59	178.4	173.6	8.613	3.536	10.20
Year	1731.9	766.85	24.99	1909.0	1853.4	101.415	44.069	99.29

Legends:
GlobHor — Horizontal global irradiation
DiffHor — Horizontal diffuse irradiation
T Amb — Ambient Temperature
GlobInc — Global incident in coll. plane
GlobEff — Effective Global, corr. for IAM and shadings
E Load — Energy need of the user (Load)
E User — Energy supplied to the user
E_Grid — Energy injected into grid

Comparison between theoretical result and simulation result

From our previous calculation, our theoretically calculated energy production is 777.33MWh/year and the energy production using PVSYST software is 770.9MWh/year. For energy generation per year, the theoretical value is nearly the same as the simulation result. For the designed system capacity, our theoretical value is a little bit far away from the simulation result.

Conclusion

We are facing fuel shortage for electricity generation and in the near future, the whole world is going to face the same scarcity because of the world's limited fuel stock. So the demand and research of renewable energy through the worldwide are rising day by day and our government is also taking steps for green energy. Khwaja Yunus Ali University has a huge opportunity to produce electricity from rooftop solar. In 2018, the university needs 110MWh – 120MWh. Initially, KYAU wants to install at student's Hall grid-tied rooftop solar to meet the present demand. This amount can be easily fulfilled by the student's Hall grid-tied solar because its estimative and simulative energy production is about 140MWh/year. For future use, KYAU can install rooftop solar at academic building and departmental new building which can produce respectively 230MWh/year and 400MWh/year. We also observe from the simulation result that solar fraction SF percentage is average 43-48%. So, we can choose solar energy for KYAU as the secondary energy source and this solar energy will contribute 48% of the total energy. The project payback return is about twelve years and the warranty is twenty-five years. And the university will be able to use this solar system freely with low maintenance cost in the next thirteen years.

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