ISSN:2348-2079

Volume-7 Issue-4

International Journal of Intellectual Advancements and Research in Engineering Computations

# Design and Simulation of 100 kWp Solar Photovoltaic (PV) Grid Connected Power Plant Using PVsyst

**Mrs.V.Kavithamani[1], P.R.Bijisha[2]**

Jai Shriram Engineering College, Avinashipalayam, Tiruppur, Tamil Nadu 641665

## ABSTRACT

This project aims to design and evaluate the grid connected solar photo-voltaic roof-top system for academic campus. The performance of the photovoltaic system depends on geographical location, solar irradiance and type of PV module & orientation of the module. This work involves theoretical analysis along with the simulation of the PV system based on different load conditions in a building to achieve maximum power, performance ratio and efficiency. The analyses of the simulation results show that the project yields energy about 110kWp for Area of academic campus is 621m$^{2.}$ The process of electricity generation from solar photovoltaic system could save 20 tons of carbon dioxide

**Keywords:** Solar Energy, Solar PV Plant, PVsyst, Photovoltaic.

## INT RODUCTION

India has taken initiatives for promotion and use of green energy technologies both in academic practice and implementation under the development of Solar Institutional campus Programme by India ministry [1]. Grid-connected solar photovoltaic (PV) systems employ the direct conversion of sunlight into electricity which is fed directly into the electricity grid without the storage in batteries. Building integrated PV system does not require any excessive space. This option, like many other renewable energy options, is generally carbon free or carbon neutral and as such does not emit greenhouse gases during its operation, since global warming and climate change are mostly caused by the release of carbon dioxide and other greenhouse gases into the atmosphere.

In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual global radiation varies from 1600 to 2200kWh/square meter, which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year [3]. India declared in its solar mission a goal of producing

22GW of electricity from solar energy by 2022 [4]. Energy production capacity of solar is very little compared to other countries. Grid Connected photovoltaic system has been generated 30,000MW in India and ~973MW stand alone systems in January 2014 [5]. Estimated PV growth is to around 100 MW in 2022, till now about 592,000 solar street and home lighting systems and 7300 agricultural pumps have been running in the rural area [6]. India's solar mission is structured in three phase in 2010: the purpose is to achieve the target 1

GW of grid-connected solar by 2013, the second 4GW by 2017 and the final to reach 22GW of PV capacity for power generation by the year of 2022. India stands now over 1GW PV capacity all over country [7].

### System Design and Objectives

The objective of this study is to design a PV system suited for the needs of the user and exploring possible PV system solutions which includes:

**Author for correspondence:**

Department of Computer Science and Engineering, Nandha Engineering College (Autonomous), Erode,

- Collecting and evaluating meteorological data for the site to determine the available solar resource and environmental conditions.
- Evaluating available ground surfaces regarding the suitability of installing a PV system.
- Designing and simulating several possible PV systems while considering limitations and restrictions.
- Evaluating the economical feasibility of the PV
- Systems designed.

## METHODOLOGY

### Simulatin Software: PVsyst

PVs yst was s elected as the simulation software, because it is a powerful tool for studying, sizing and analyzing data of a PV system. It contains databases of both meteorological data and PV s ys tem components fro m several manufacturers. For this study version 6.77 evaluation mode is us ed. Figure 1 shows an outline of the different s teps in performing a PV system design and simulation in PVsyst.

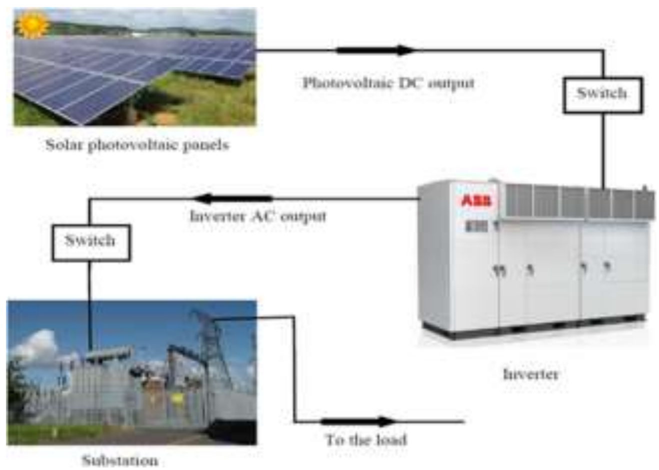



**Fig. 1. Project design steps in P Vsyst [3]**

### Site Assessment

During the site assessment, available area for installation, orientation and dimensions, near shading objects, and electricity consumption pattern were investigated. The proposed site is located at Kovilpalayam, Avinasipalayam, Tirupur. The geographical location is listed in Table 1. These coordinates were used for all weather data and site specific data throughout the study.

**Table 1. Geopgrahical Location of Ibabao, Aloran**

| Latitude | Longitude | Altitude | Time Zone |
|---|---|---|---|
| 10.97 | 77.43 | 328m | +8.0 |


**Fig. 2. Satellite imagery of the location**

**Fig. 3. Actual image of the site**

3.3 hectares of land is identified. No wildlife and no archaeological monument exis t at the proposed site. The site is well connected by a road and no health hazards are caus ed by s olar plant.

## Meteorological data

The meteorological data file can be chosen from one of the databases included in PVs yst, which are NASA -SSE and Meteonorm 7.1, imported from another database that PVsyst supports or created based on measured data from e.g. weather stations. The required parameters in the meteorological file are horizontal global irradiance and ambient temperature. Horizontal diffuse irradiance and wind velocity are optional parameters, but the result will be more accurate if they are included. Since the simulation in PVs yst is operated at hourly intervals, hourly meteorological data are required to perform a simulation. For the meteorological data sources only containing monthly data, synthetic hourly data are constructed from the monthly values . Table 2 shows the Acquired meteorological data from the specified site based on Meteonorm 7.1 database. Hourly meteorological data was synthetically generated for the databases that only had monthly values.

## Selection of module and inverter

Selecting a module to us e may be challenging as there are numerous modules available in sizes, power, types, prices and efficiency from multiple manufacturers. It is important to make sure that the module co mplies with IEC standards for module design and quality and investigate the module warranty. Another factor to consider is which modules are available in the country and which modules installers are familiar with. Based on the Ohm Home summary recommendation of solar modules available on the market today, Canadian Sola r (CS) was listed as one of the top preferred module brand as of 2017 [4]. The CS6U-

330P solar module was distinguished having substantial efficiency in CS6U Series with 18.85% efficiency per cells area. The modules have to be oriented in lands cape configuration to avoid the effect of parallels hading on the module cells [3].

**Table 3. Canadian solar cs6u-330p**

| | |
|---|---|
| Technology | Si-Poly |
| Nom. Power (STC) | 110 Wp |
| Operating voltage | 31.7 V |
| Voc (-10°C) | 50.9 V |
| Number of modules | 324(18 in |
| Vmax (IEC) | 1500 V |
| Efficiency/Module | 629m2 |

When selecting the inverter, consideration should be made of the size of the system, cost, flexibility of the system, partialshading, number of substrings or strings and their orientation. Care should be taken to ensure that only modules with the same orientation, angle and shading conditions are connected together in strings. The selected string inverter for the design was chosen based on recommendation from Clean Energy Reviews [5]. The most used inverter brand for PV systems in the 11 - 99 kWp range is SMA [6]. The SMA Sunny Tripower 10000TLEE inverter was used in all ground mounted simulations.

**Table 4. Sma sunny tripower 10000tlee inverter**

| **Input side (DC PV Field)** | |
|---|---|
| Minimum MPP Voltage | 300 V |
| Maximum MPP Voltage | 590 V |
| Absolute max. PV Voltage | 600 V |
| **Output side (AC Grid)** | |
| Triphased | 50/60 Hz |
| Grid Voltage | 202 V |
| Nominal AC Power | 10.0 kW |
| Maximum Efficiency | 97.80% |

The manufacturer's specifications were based on original PVsyst database.

## Module orientation and inter-row spacing

The field type of a ground mounted PV system can be chosen as either a fixed tilted plane or unlimited sheds in PVsyst. A shed in PVsyst is a row of modules. When using a fixed tilted plane, the module rows are constructed in the near shading scene. Both mutual shading and near shading items are therefore accounted for. A fixed tilted plane is used and unlimited sheds is defined on near shadings optional parameters to specify module layout. The energy production will be optimized for a yearly irradiation yield. When choosing the tilt angle and azimuth angle for a ground mounted PV system, the inter-row spacing must be considered together with the orientation. An optimization between tilt angle, azimuth angle, area utilization and maximum energy production is ideal when choosing the inter-row spacing. In this design, the optimization by respect to yearly irradiation yield and the condition of no mutual

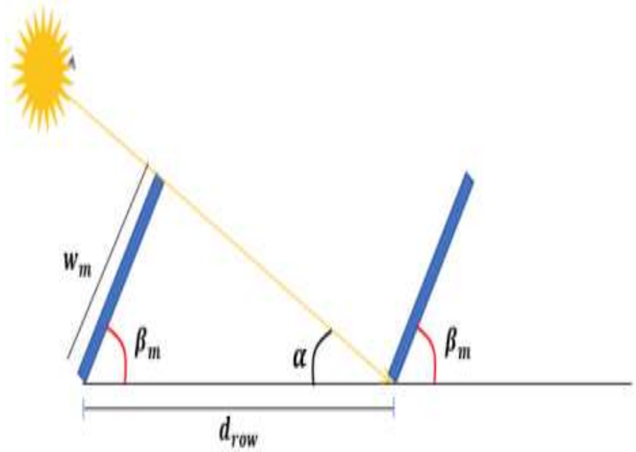



**Fig. 4. Inter-row spacing for a ground mounted PV system.**

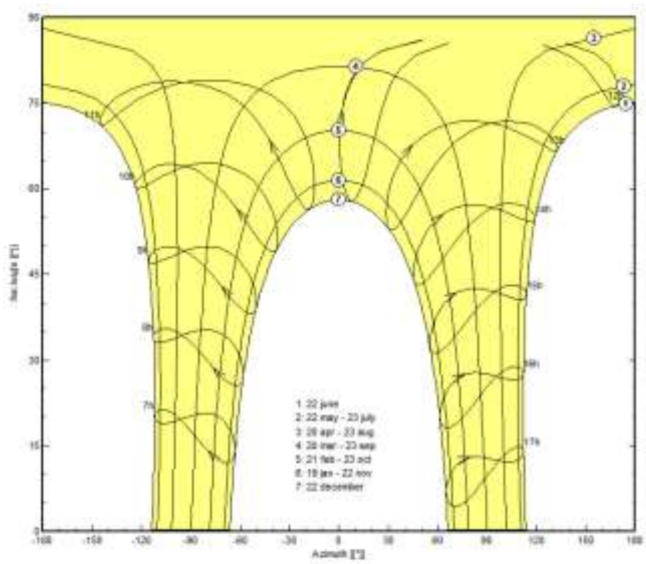


**Fig. 5. Solar Paths at Aloran – Legal Time**

As to indicate how well the system is designed, parameters related to their performance are calculated. Specific y ield Yf [kWh/kWp], also called final system yield, is the energy produced by the system, E, with respect to its nominal power. It is an indicator of the potential of the system and is given by an be classified as temporary, resulting from location or caused by the PV system. PVsyst distinguishes near shading produced by objects clos e to the PV module. An analys is of the effect of nears hading objects on the PV system was made for the available ground area.

PVs ys t calculates the lower and upper voltage limit for a module and suggests a min imu m and maximum amount of modules in a string for a given inverter. To estimate the minimum and maximum number of modules in a string, the module operating temperatures and module voltages were calculated. The desired load no mina l power for the design is

100 kWp. Then the program will choose the required number of inverters, according to Pnomarray/inverter ratio of 1.25. PVs ys t will then propos e a number of modules in series, and

number of strings in order to approach the des ired power.

It includes also sub-station and its components like transformers, etc., which is essential for grid connection. DC/AC cables are required for connecting panels, inverter and to the grid. This research is aimed at fulfilling the research gap of comprehensive and complete feasibility ana- lysis of solar campus which is missing in previous research. Also there is a scarcity of data related to the development of the sustainable green campus in India.

$$Y_f = \frac{E}{P_{nom\ array}}$$

and Performance Ratio (PR) repres ents the system efficiency with respect to the nominal power and the incident energy. PR includes array and s ystem los s es and is an indicator of the quality of the s ys tem. It is given by

$$PR = \frac{Y_f}{Y_r}$$

PVs ys t calculates the lower and upper voltage limit for a module and suggests a minimum and maximum a mount of modules in a string for a given inverter. To estimate the minimum and maximum number of modules in a string, the module operating temperatures and module voltages were calculated. The des ired load no mina l power for the design is

100 kWp. Then the program will choose the required number of inverters, according to Pnomarray/inverter ratio of 1.25. PVs ys t will then propos e a number of modules in series, and number of strings in order to approach the desired power.

For 100 kWp as a desired load nominal power, 10 numbers of inverters were needed to provide a global inverter's power of 100 kWac. 10 number of modules in series and 30 number of strings to produce an Array No mina l Power of 99.0 kWp STC. PVsyst then calculates the needed modules which are approximately 300 modules and with an available area of 583 square meters. PVsyst will then able to show the operating conditions based on the manufacturer's sspecification (Table 6).

**Table 5. Array design**

| Planned Power | 100 |
|---|---|
| Number of Inverters | 10 |
| Global Inverter's | 100 |
| Module in Series | 10 |
| Number of Strings | 30 |
| Number of Modules | 300 |
| Area | 583 |
| Array Nom. Power (S | 99.0 |
| Pnom Ratio | 0.99 |

**Table 6. Operating conditions**

| | |
|---|---|
| Vm pp | 31 |
| Vm pp | 37 |
| Voc (- | 50 |

## Shading

Shading on a PV module reduces the power output and can cause heating in a solar cell. The shadings cenario of the installation site is therefore important to survey Shading

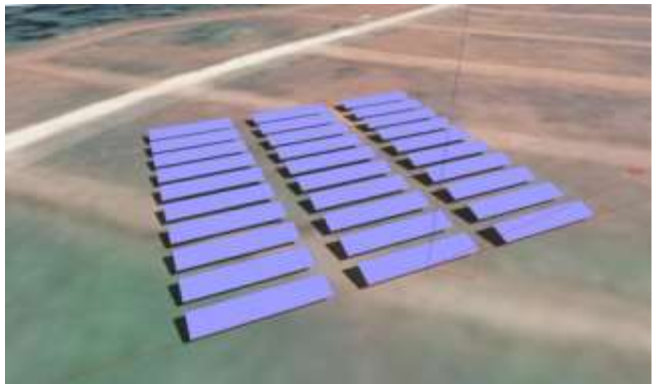


**Fig. 6. Area t hat was used in the shading analysis, 601 m².**

Shading on the ground area mainly occurs during winter months, as the Sun's position in the sky is lower. Due to the chosen inter-row s pacing, no mutual shading occurs from

7a m to 4p m during the winter months. The shading is ma inly due to mutual shading between the module rows in mornings and afternoons .

## Transformer

Transformer is a static device which transforms power from one source to another source without changing frequency. Transformer always has a unity power factor. It doesn't have lagging and leading power factor. Ma inly transformer power factor depends on load power factor. The rated transformer M VA should be the same as the rated MVA o f the inverter(s) connected with the transformer r [7].

## Balance of System (BoS) Components

Other components required for a working PV system are called the balance of system. Other BoS components in a grid-connected PV system include AC and DC cabling, a monitoring system, metering and protection and dis connection switches. A protection, dis connection and metering scheme for a g rid -connected PV s system is illustrated in Figure 7.

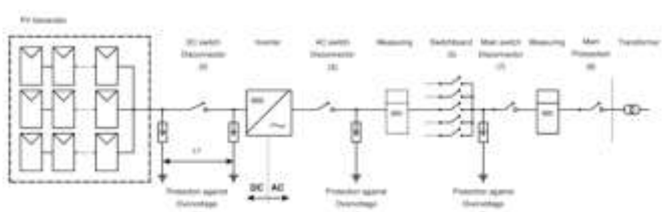



**Fig 7. Grid-connect ed P V syst em and over-volt age protect ion scheme [8].**

## Economical evaluation of a PV system

When investing in a PV system, the investor is interested in a system that gives a reasonable profit.

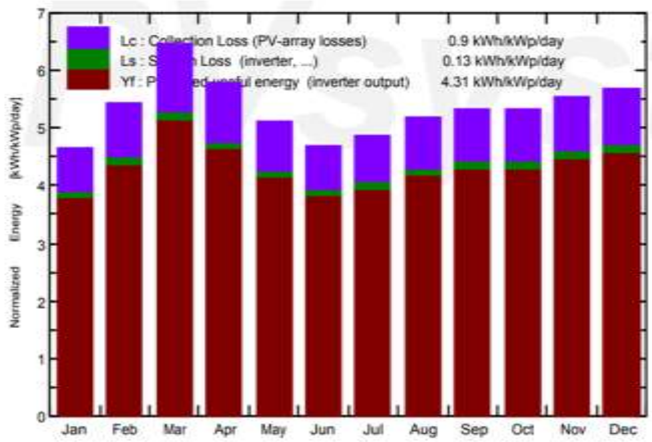
## Payback Time

The payback time is defined as the amount of time it takes to recover the cost of an investment. It is defined as [9]

Table 7 shows the simulation results for the ground mounted systems . The monthly normalized production and PR for the sys tem is shown in Figure 9 and Figure 10.

**Table 7. Results overview**

| | |
|---|---|
| System Production | 156 MWh/yr |
| S peci fi c Production | 1573 kWh/kWp/yr |
| Pe rforman ce Ratio | 0.808 |
| Normalized Production | 4.31 kWh/kWp/day |
| Array Losses | 0.90 kWh/kWp/day |
| Sys tem Losses | 0.13 kWh/kWp/day |




payback time =total investment / annual income

## Net Present Value (NPV)

The Net Pres ent Va lue (NPV) method is us ed to calculate the pres ent value of the future cas h flows and is a common way of eva luating a PV s ys tem. A project is cons idered profitable if the NPV > 0 [10]. The payback time s hows how long it will take to ma ke the inves ted mone y back, while NPV s hows the profit one can e xpect at the end of the inves tment period. The pres ent value of the lifecycle costs is calculated by [11]

$$NPV = \sum_{t=0}^{T} \frac{Revenue_t - Costs_t}{(1 + r)^t}$$

where $t$ is the year of operation , $Ct$ is the net cas h flo w, $T$ is the lifetime of the s ys tem, $r$ is the dis count rate, *Revenuet* is the cash inflow and *Costst* is the cas h outflow.

## RESULT S AND DISCUSSION

When performing a s imulat ion, PVs ys t produces a s ix page report containing the s ys tem configuration and s imu lation res ults . PVs ys t calculates the los s es and s hows them in a los s diagram as illus trated in Figure 8. The upper parts of the diagram are optica l los s es, the middle parts are array los s es, and lower part are s ystem los s es.

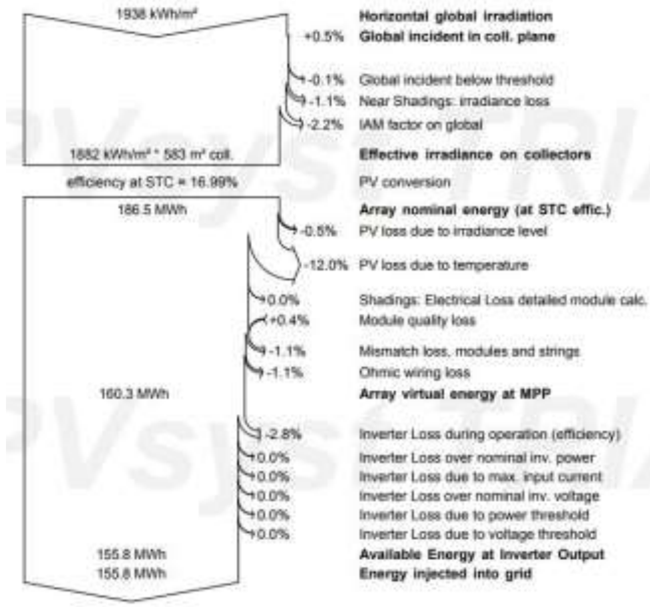



**Fig. 8. Loss diagram over the whole year.**

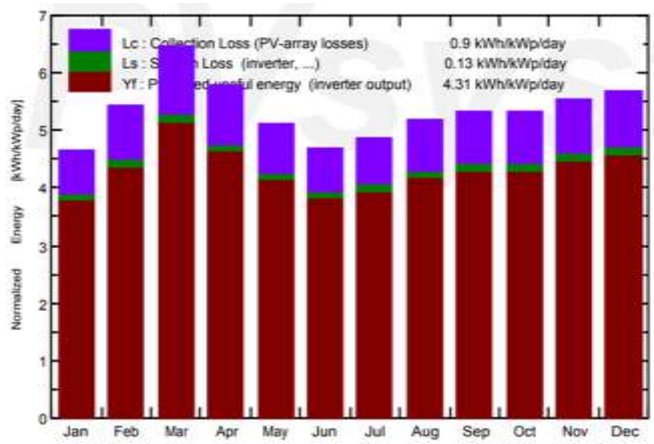



**Fig. 9. Normalized product ions (per inst alled kWp): Nominal Power 99.0 kwp**

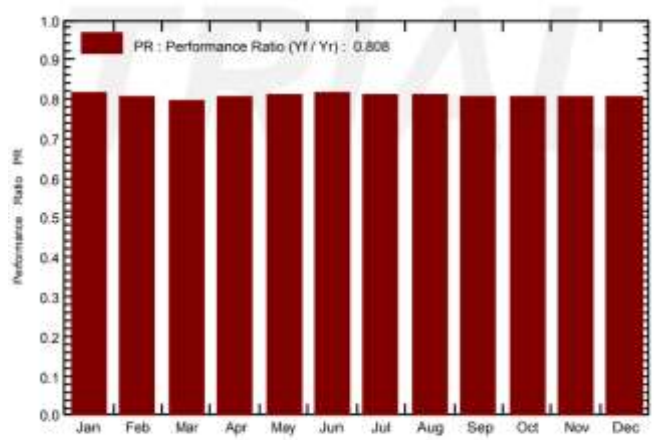



**Fig. 10. P erformance Rat io**

Near s hading irradiance los s and IAM loss were the larges t optical los s es . The array and s ys tem los s es that had the greates t effect on s ystem performance we re inverter loss and effic iency los s due to temperatures difference from STC, as s hown in Figure 8.

The performance ratio is higher during winter months than during s ummer months, as can be obs erved in Figure 10. This is e xpected as winter months have lower temperatures and s oiling, res ulting in lower los s es . The norma lized production for each month s een in Figure 9 s hows the array and s ys tem los s es. Both los s es are lowe r during winter months and increas e during s ummer months. The array los s es increas e s ignificantly during s umme r months, as it includes the effic iency los s due to temperature.

## Economic Evaluation

After s imu lation, an economic evaluation o f the s ys tem was performed on the bas is of the defined parameters and the s imulat ion res ults . Cos ts are defined globally in price lis t fro m co mponents databas e and manufacturer online quotation.

**Table 8. Economical assump tions**

| **In ves tment** | **Qty.** | **Price/Unit** | **Total (Php)** |
|---|---|---|---|
| P V modules (P nom = 330 Wp) | 300 | 12,854/module | 3,856,260 |
| Support s/Int egrat ion | | 1,574/module | 47,2281 |
| Inverters(P nom = 10.0 kWac) | 10 | 11,5914/unit | 1,159,136 |
| Set t ings, wiring, … | | | 607,218 |
| Electrical Installat ion | | | 409,309 |
| Project Management | | | 167,172 |
| Commissioning | | | 13,494 |
| Transport and assembly | | | 76,090 |
| Engineering and draughting | | | 30,736 |
| Subst it ut ion underworth | | | -50,000 |
| **Gross In vestment (wi thou t taxes)** | | | **6,741,694** |

| **Fin ancin g** | | |
|---|---|---|
| Gross investment (wit hout t | 6,741,694 | |
| Taxes on Investment (VAT ) | Rat e 9.2% | 620,236 |
| Gross Investment | 7,361,930 | |
| Subsidies | -15,730 | |
| **Ne t In ves tment** | 7,346,200 | |
| Annuit ies | Loan 5.0% | 589,478/y |
| Annual running cost s: | 67,917/yr | |
| **Total yearly cos t** | **657,395 Ph p/yr** | |

| **En e rgy Cos t** | |
|---|---|
| Produced Energy | 156 |
| Cost of produced | 4.22 P |

Prices are defined and discounts are ass umed for several pieces bas ed on the manufacturer's cost. The net investment - for the owner - is derived from the gross inves tment by subtracting potential s ubs idies and adding a tax percentage (VAT). Choos ing loan duration and interest rate, PVs yst computes the annual financial cost, suppos ing a loan pay back as constant annuities . The loan duration correspond to the expected lifetime of the sys tem. This procedure is justified by the fact that, as a contrary to a usual energetic installation, when purchas ing a solar equipment the customer buys at a time the value of the whole energy cons umed during the exploitation [12]. The sum of the annuities and the running cos ts is the total annual cost. Divided by the effectively produced and used energy, it gives an evaluation of the energy cost (price of the us ed kWh) [12].

Table 9 shows the result of the calculation of payback time and NPV. The s ystem lifetime is as sumed to be equal to the module lifet ime. The Intern ational Energy Agency (IEA ) ass umes a PV s ys tem lifet ime of 25 years [13 ]. The IEA als o ass umes dis count rates between 3% and 10% with an average of 7% [13]. A dis count rate of 7% corres ponds to the ma rket rate in deregulated or res tructured ma rkets, while a rate of 10 % corres ponds to investments in a high-ris k ma rket [13].

**Table 9. Payback time and npv**

| | |
|---|---|
| P ayback Time | 11 |
| Net P resent | 1434 |

The economica l evaluation s hows that it will take 11 years to make the inves ted money back and the net pres ent value is pos itive for a ll s ys tems . This means that the inves tment cost will be paid back during the s ys tem lifetime .

## CONCLUSION AND ECOMMENDATIONS

Us ing the PVs ys t s imulation s oftware, the energy yield analys is for 100 kWp PV s olar powe r generation was performed for geographical s ite at Ibabao, Aloran, Mis a mis Occidental. A lthough, there are uncertainties regarding the meteorologica l data and the available s olar res ource. SolarGIS depict a global irradiat ion of 1854 kWh/m² while Meteonorm has 1937.6 kWh/m². Changes in irradiation data increas ed the s ys tem yield by 5%. It is difficult to conclude which meteorological datas et is mos t repres entative for the climate conditions at Aloran.

It is obs erved that the efficiency of modules is more sensitive to temperature than the s olar irradiat ion. The norma l da ily wis e is that the effic iency of the plant is high during morning t ime but low during middle of the day and s tarts increas ing from late afternoon. The efficiency of modules varies fro m 14.5% to 11.5% with variat ion in the averaged module te mperature fro m 25°C to 60° C. Hence cooling of s olar modules may be des irable to increas e the efficiency.

There were many ass umptions and s implifications in the economical evaluation, which ma kes the res ults debatable . Interes t payments and inflation we re not cons idered . The component prices depend on t he quantities bought and the BoS prices depends on the chos en monitoring s ys tem.

### Further Work

More detailed informat ion regarding the electrical layout, poss ible mechanica l load, dimens ioning for the mounting s tructure and protection, dis connection s witches and metering is needed. An analys is of the ground s oiling type may also be needed. There is als o a wide s election o f other module and inverter technology available on the market today. Other s ys tems could also be evaluated and compared with res pect to performance and price. The uncertainties in the economica l evaluation could be further ass es s ed by collecting informat ion from several PV system companies regard ing cos ts to compare them.

## REFE RENCES

[1]. Department of Energy. Dist ribut ion Development P lan 2010 – 2019. Retrieved December 7, 2018, from htt ps://www.doe.gov.ph/sit es/default /files/pdf /elect ric_power/develop ment _plans/ddp_2010-2019.pdf

[2]. Cabahug-Aguhob, R. (2012, April 27). MOELCI 1 to purchase energy from other sources to solve generat ion deficiency in franchise area. Retrieved December 07, 2018, from htt p://www.ugnayan.com/ph/MisamisOccident al/Calamba/art icle/1SQ W

[3]. Pvsyst cont ext ual help (built -in soft ware). URL http://files.pvsyst.com/help/index.html

[4]. OhmHome. (n.d.). 2017 Best Solar P anel Brands - Ranking and Trends. Retrieved December 7, 2018, from htt ps://www.ohmhomenow.com/best-solar-panel-brands/.

[5]. Svarc, J. (2018, May 12). Best Solar Inverters 2018. Retrieved December 7, 2018, from htt ps://www.cleanenergyreviews.info/blog/best -grid-connect-solar- invert ers-sma-fronius-solaredge-abb

[6]. Klever, M. (2018). Design and simulation of a gridconnected PV system in South Africa: Technical, commercial and econom ical aspects (Unpublished mast er's thesis). Norwegian University of Life Sciences. Ret rieved December 7, 2018, from htt p://hdl.handle.net /11250/2500547

[7]. V, V. (2015, August 31). T RANSFORMER SIZING FACTOR FOR SOLAR P V P OWER PLANT S. Retrieved December 8, 2018, from htt ps://www.linkedin.com/pulse/transformer-sizing-fact or-solar-pv-power-plant s-v-r-v/

[8]. P V shop. P V solar system diagram. URL. htt p://pvshop.eu/diagrams.html. Accessed 12.07.2018.

[9]. Arno H. M. Smet s, Klaus J¨ager, Olindo Isabella, Ren´e A. C. M. M. van Swaaij, and Miro Zeman. Solar energy: the physics and engineering of phot ovolt aic conversion, t echnologies and syst ems. UIT Cambridge, Cambridge, 2016. ISBN 978-1-906860- 32-5.

[10]. Johannes Idsø. N˚averdi. URL htt ps://snl.no/n%C3%A5verdi. Accessed 27.01.2018.

[11]. Set h B. Darling, Fengqi You, Thomas Veselka, and Alfonso Velosa. Assumpt ions and the levelized cost of energy for photovoltaics. Energy Environ. Sci., 4:3133 –3139, 2011.

[12]. P Vsyst. (2018,November). Economic evaluat ion. Ret rieved from http://files.pvsyst.com/help/economic_evaluat ion.htm

[13]. Michael Taylor and Eun young So. Project ed Cost s of Generat ing Electricity 2015 edit ion, . URL htt ps://www.iea.org/publicat ions/freepublicat ions/publicat ion/ projected-cost s-of-generat ing-elect ricity-2015-edit ion.html.