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Solar Power Installation Simulation in SDN Rancagong 1 and 4 Using PVSyst to Support the Physical Standard of Comfort

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ABSTRAK

Kenyamanan dalam belajar membutuhkan penggunaan peralatan listrik yang baik dan mendukung proses pembelajaran. Untuk meningkatkan kenyamanan, penggunaan peralatan listrik perlu dimaksimalkan, yang dapat berakibat pada konsumsi energi listrik lebih tinggi. Sebagian besar energi primer untuk pembangkit listrik berasal dari sumber tidak terbarukan yang menghasilkan polusi. Tidak semua daerah di Indonesia dapat menggunakan listrik dan menjaga standar kenyamanan yang diinginkan. Salah satunya adalah SDN Rancagong 1 dan 4, di mana penggunaan alat listrik masih minim untuk menunjang proses pembelajaran. Berdasarkan pengukuran standar kenyamanan, ditemukan bahwa suhu udara melebihi 4°C dari standar SNI 03-6572-2001, kelembaban melebihi standar yang sama sebesar 9%, serta iluminasi yang hanya mencapai kurang dari sepertiga standar pencahayaan SNI 6072-2020. Hasil survei terhadap penhuni ruangan juga mendukung temuan ini secara kualitatif. Oleh karena itu, diusulkan penggunaan energi terbarukan seperti pembangkit listrik tengara surya. Untuk menghindari kerugian dan tindakan yang tidak efektif, dilakukan simulasi dengan perangkat lunak PVSyst dalam penelitian ini. Ditemukan bahwa daya yang dihasilkan adalah 7829.33 kWh per tahun, dengan rasio kinerja sebesar 49%, fraksi tenaga surya sebesar 100%, siklus SOW 98.4%, dan statik SOW sebesar 90%. Dengan daya yang diperoleh ini, diharapkan dapat membantu penyediaan listrik untuk peralatan yang dapat meningkatkan standar kenyamanan seperti penyejuk udara atau lampu tambahan.

Kata kunci: kenyamanan, energi listrik; pembangkit listrik tenaga surya; PVSyst

ABSTRACT

Physical comfort in the learning environment relies on the use of good electrical equipment, which significantly supports the learning process. To enhance comfort, it is essential to maximize the use of electrical appliances, although this can lead to increased energy consumption. Most of the primary energy for power generation comes from non-renewable sources, which contribute to pollution. In Indonesia, not all regions have access to electricity that meets desired comfort standards. One such area is SDN Rancagong 1 and 4, where the use of power tools to support the learning process is still minimal. Measurements of comfort standards revealed that the air temperature exceeded the SNI 03-6572-2001 standard by 4°C, while humidity levels surpassed the same standard by 9%. Additionally, illumination levels were less than a third of the SNI 6072-2020 lighting standard. Qualitative feedback from room occupants supports these findings. To address these issues, the proposal includes the use of renewable energy sources such as solar energy. To avoid losses and ensure effective implementation, simulations were conducted using PVSyst software. The results indicated a power generation potential of 7,829.33 kWh per year, with a performance ratio of 49%, a solar fraction of 100%, an SOW cycle of 98.4%, and a static SOW of 90%. With this power output, it is anticipated that electricity can be provided for equipment that enhances comfort standards, such as air conditioning and additional lighting.

Keywords: *physical comfort; electricity; solar energy; PVSyst*

I. INTRODUCTION

Physical comfort provision, consisting of thermal, humidity, and lighting (as well as other physical aspects), for building occupants becomes the most important part that ensures the well-being of the indoor environment (Ahlawat et al., 2020; Alotaibi et al., 2020; Boyce et al., 2022; Kurniawan et al., 2019; Parkinson et al., 2020; Stefani & Cajochen, 2021; Wojnicki et al., 2019). Many categories lie in this physical comfort, such as thermal, humidity, lighting, and others. These physical aspects must never be overlooked because it greatly affects occupants' condition (Kurniawan et al., 2019; Parkinson et al., 2020; Stefani & Cajochen, 2021; Wojnicki et al., 2019). In thermal discomfort cases, many occupants, such as hospital patients, felt the adverse effects on their sleep quality (Alotaibi et al., 2020). Relative humidity can also change the state of bacterial development, which is critical in this case (Ahlawat et al., 2020; Alotaibi et al., 2020). For rooms with machines such as server rooms, it is vital to protect the temperature and humidity at its best for the computers and system to work properly (Kurniawan et al., 2019).

In the sense that the physical standard of comfort immensely affects the occupants and the indoor environment, it is certainly important for the need of suitable building architectural design and system as a means to eliminate this problem (Parkinson et al., 2020). For challenges such as changing climate conditions, passive design such as natural ventilation and natural lighting can help in supporting the maintenance of the physical standard of comfort, occupants' health and condition, as well as reducing the usage of energy excessively (Gago et al., 2015; Michael & Heracleous, 2017; Parkinson et al., 2020; Saleem et al., 2016). Mentioning energy, the use of passive design is made to reduce the energy consumption that may affect the cost of buildings from artificial system (active system) which mainly uses electricity. Nonetheless, several places are in dire in the need towards the use of electricity by its active system to support the occupants' activities such as hospitals and schools.

Indonesia is one of the many countries that rely on electricity, which mainly produced from non-renewable energy sources. It cannot be denied that its consumption has greatly impacted the environment and living things due to the pollution produced (Sharma et al., 2021). Renewable energy is used to overcome this issue since it is environmentally friendly and serves as a continual-sustained source (Bei & Wang, 2023). In Indonesia, the potential for renewable energy is still unutilized fully (Langer et al., 2021). With this potential, opportunities are arising to install renewable energy power plants in suitable locations. In consideration of the condition of several Indonesia village having difficulties towards electricity access and usage, in which its facilities such as schools are facing the same problem, SDN Rancagong 1 and 4 are chosen. This place is also tested to see the necessities of electricity tools installation based on the physical standard of comfort mentioned earlier.

As a fact that schools are the place where students as future generations get education that can make a better improvement for the world, it is important to ensure that it is in the best condition to maximize all studying process (Ryan Restyawan, 2017). Yet, with the condition where facilities are not maximally presented, such as the use of electricity for tools like air conditioners, lamps, and others, it will be fatal to the school' system and the students. Moreover, it is also known that the electricity demand increases along with the increase of population in the village, in which its schools will also be impacted (Khair & Ashari, 2021; Sumbung et al., 2016). Thus, the chosen schools are surveyed and conducted to see the suitability of installing solar power as renewable energy implementation to support school activities for a better future to the next generation.

SDN Rancagong 1 and 4 is a primary school located at Rancagong Village, Legok, Tangerang, Banten. This village is one of the many villages in Indonesia that lacks the support for electricity usage which has been verified according to the author's several visits and surveys to other facilities (such as village head office). SDN Rancagong 1 and 4 are two separate schools located at the same building in which the way to differentiated them are based on the time shift spent by students and teachers. SDN Rancagong 1 has a total of 271 students and 12 teachers with the activity time from 07.30 to 12.30. Whilst, SDN Rancagong 4 has a total of 168 students and 9 teachers with the activity time from 13.00-16.30. The building has 12 rooms, in which 6 are allocated for class, 2 for teacher's office, 1 library, 1 principal's office, and the final two are under construction. In detail, each class will be used by different schools (such as students of grade 5 of SDN 1 and grade 3 for SDN 4 etc. according to the time shift). Each class usually is occupied by 30-50 students with the size of the class relatively not large for that capacity.

Facilities and electrical tools provided by the schools that are noticed consist of a total of 20 LED lamp that are placed in several classes, of which 5 are not working, 2 Wi-Fi routers, 1 speaker, a photocopy machine, and a printer machine, 6 fans, 1 bell, and 1 water pump. The lamps are never opened unless the weather is rainy and only at night for 5-6 hours. The others are used occasionally. With these discoveries of the school's condition, some assessments towards the comfort standard (lighting, thermal, and humidity) are made to support the finding for the electricity underuse in SDN Rancagong 1 and 4 as a means to show the need for electricity for them, which will be discussed further.

Using the results from the findings, it is obtained that there is a need to use electrical tools to support the physical comfort standard. This can be solved by adding the use of electricity. However, with the current condition, it is not preferable to use electricity provided by the government since it is costly. The alternative way is to use renewable energy technology. After surveys and research are done towards renewable energy potential, the most suitable energy that can be used obtained in SDN Rancagong 1 and 4 is solar power. Knowing that it is inefficient for installing this energy without preparation to avoid unnecessary losses and ineffectiveness, simulation using software, one such as PVSyst is proposed. PVSyst is a software used to operate clean energy operation analysis tests using PV cells for the chosen location (Suriadi & Mahdi Syukri, 2010). PVSyst has many features which are analysis results of the PV system that consists of outcome of the system, production data, settings for PV and inverter product, and many more by a Mean Bias Error (MBE) of approximately 1–2% (PVSyst, 2023; Saputri et al., 2023a).

PVSyst has been used in numerous studies, ranging from grid-connected to off-grid systems, demonstrating the analytical capabilities offered by this software.(Ahmad et al., 2019; Grover et al., 2020; Mishra et al., 2024; Saputri et al., 2023b; Suriadi & Mahdi Syukri, 2010). The study of the solar power plant design in Pekanbaru revealed a generation of over 23 MWh, utilizing more than 40,000 Longi Solar modules (415 Wp), as indicated by the PVSyst simulation (Saputri et al., 2023b). Another study utilizes a PVSyst simulation of 5 MWp, comparing it to real generation data. The simulation shows a higher estimation in system efficiency by 0.12% and a lower performance ratio by 0.60%, indicating its accuracy and potential as a reliable tool.(Mishra et al., 2024). In comparison, this study will use PVSyst to simulate solar energy potential as a mean to supply power based on the selected area which is SDN Rancagong 1 and 4.

Hence, this paper depicts a study and analysis using PVSyst as software to simulate the solar power implementation as a renewable energy to provide electricity in supporting the condition occurred in SDN Rancagong 1 and 4. The aim is to demonstrate the possibility and potential of solar power that can be generated in the area. The method of this study is mainly based on quantitative data of electrical appliances used in the schools and supportive qualitative data of physical standard surveys by students. Furthermore, this study will discuss the finding results for physical standard of comfort to show how important the electricity presence can help significantly towards a better studying process in SDN Rancagong 1 and 4.

II. METHODS

The methods in this research involve several procedural stages from problem identification to conclusions which can be depicted in the following flowchart.

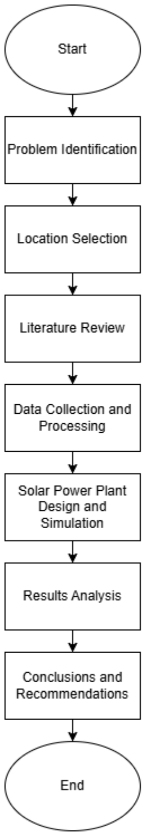

Figure 1. Research Flowchart

For a detailed explanation, several sections from data collection, data processing and analysis, and solar power plant design are elaborated below.

A. Data Collection

The data used in this study comprised administrative and technical data. This study collected data using several methods.

1. Visit and Observation: Systematic observation is performed within the surroundings and interior of SDN Rancagong 1 and 4. The visit is intended to record the latest data on the number of electrical tools, electricity cost, number of occupants, and physical standard of comfort (lighting, thermal, and humidity). Based on the visit, it was recorded that there is minimal to no use for active systems in most of the classes (see Figure 2). The standard of comfort was measured using an instrument called the environment meter DT-8820, which has four features to measure illuminance, sound, humidity, and temperature. For the thermal standards of comfort or temperature measurement, six student classes were used, each of which was divided into five segments (location points) to be measured one time. For three offices (teachers and principals), the measurement was done within 3-point location with one repetition. This is because the temperature at that point was measured repetitively, with the same results for several classes. Therefore, it was more efficient to perform one repetition. For lighting and humidity measurements, all rooms were measured five times at five points, except for one teacher's office of SDN Rancagong 4 and the principal's office with two points of five repetitions. The division of segmentation or location points is based on room size.
2. Interview: The data collection was also conducted using interviews with the school staff to determine the condition of the school (the principal, security guard, teachers, as well as village head officers).
3. Survey: Additional surveys using questionnaires are given to reinforce the data results from the measurement, which show the necessity of electricity for school improvement. The minimum number of respondents was 210 (based on the total number of occupants of SDN Rancagong 1 and 4, which was 460). The number of respondents recorded for the survey was 281 (students and staff of SDN Rancagong 1 and 4).

Figure 2. SDN Rancagong 1 and 4 Classes

B. Data Processing

The information was organized and analyzed based on the data collected. The technical data was processed to find the average as well as the precision of the data spread on the physical standard of comfort in each class. These were then compared to the Indonesian National Standard (SNI) as a part of the analysis for renewable energy implementation. The utilized standards consist of SNI 03-6572-2001 for ventilation and air conditioning design in a building, SNI 7062-2019 for illuminance measurement in a working environment as well as SNI 6072-2020 for energy conservation for lighting systems. In specific, the required data based on the standards include temperature (Celsius degrees), relative humidity (%RH), and illuminance (lux) based on a helping measurement tool called an environment meter. This tool, namely DT-8820 features 4 parameters for measurement with the additional sound level (dB) as previously mentioned. The analysis also includes solving the problem in accordance with the findings. Survey data were collected to strengthen the results.

C. Solar Power Plant Design

Based on the data that have been assembled, it is determined that there is a need for additional power sources for electrical purposes to support SDN Rancagong 1 and 4 physical standards of comfort. The solar power plant can be designed using PVSyst software. PVSyst is a software with a system that can be classified into standalone, grid-connected, pumping, and DC grids, and is completed from meteorological sources (Atsauri et al., 2021). A simulation report of a solar power plant will be used for analysis and implementation.

III. RESULTS AND DISCUSSIONS

The analysis in this study will first focus on the results of the measurement of the physical standard of comfort. Notations used to differentiate each room are as follows:

1. Classes 1, 2, 3, and 4 were located on the left side of the entire building, whereas Classes 5 and 6 were located on the back side of the entire building.
2. Office 1 regards the principal's office, whereas Offices 2 and 3 are for teachers' offices.

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Based on the data collected, the thermal comfort (temperature-based) is shown in Figure 3.

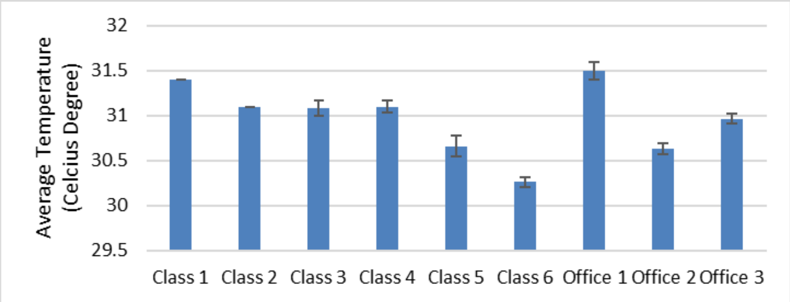

Figure 3. Graph of Temperature Measurement for Student Classes by 5 Repetitions and Offices by 3 Repetitions

Based on the graph above in which the data has been processed to find average and precision, for the average temperature, Class 1 is by 31.4℃, Class 2 by 31.1℃, Class 3 by 31.08℃, Class 4 by 31.1℃, Class 5 30.36℃, Class 6 by 30.26℃, Office 1 by 31.5℃, Office 2 by 30.63℃, and Office 3 by 30.97℃. Each class exhibited a precision of approximately 99 % for five location points in one room. Compared with the thermal standard of comfort (24℃-27℃) from SNI 03-6572-2001 the obtained results changing from 30℃ to-31℃ are far from the standard (Peraturan Menteri Energi Dan Sumber Daya Mineral Repuiblik Indonesia Nomor 13 Tahun 2012 Tentang Penghematan Pemakaian Tenaga Listrik, 2012). In addition, the rooms were without any occupations, and it was raining. If the condition is the opposite, it can be assumed that the temperature may even increase further. Therefore, it is highly recommended to use electrical tools to maintain the temperature in standards, such as air conditioners and fans, specifically for rooms that directly face the sun rays (east). Then, The humidity data are shown in Figure 4.

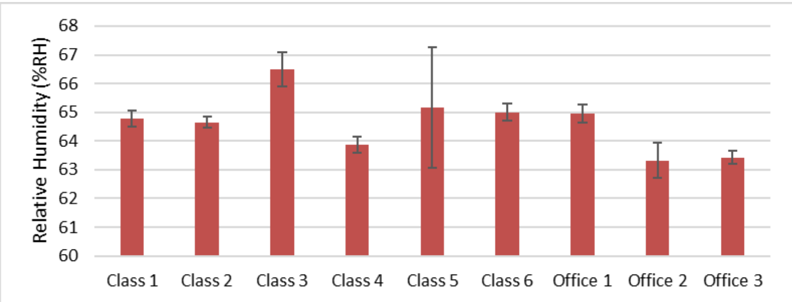

Figure 4. Graph of Average relative humidity results in Class 1-6 and Office 1-3

Based on the data in Figure 4, the humidity varied between classes. It can be seen that for Class 1, the humidity range from 64.44% - 64.96%, Class 2 from 64.54% - 64.72%, Class 3 from 66,34% - 66,56 %, Class 4 from 63.74% - 64.02%, Class 5 from 64.9% - 65.5%, Class 6 from 64.82% - 65.24%, Office 1 from 64.7% - 65.1%, Office 2 from 63.06% - 63.52%, and Office 3 from 63.7% - 64.15%. The precision of the measurements ranged from 95% to 99%. Thus, the average humidity for SDN Rancagong 1 and 4 ranged from 64% to 65%. Based on the humidity standard of comfort from SNI 03-6572-2001, the value ranges from 40-50% and 55% - 56% for fully occupied conditions (Peraturan Menteri Energi Dan Sumber Daya Mineral Repuiblik Indonesia Nomor 13 Tahun 2012 Tentang Penghematan Pemakaian Tenaga Listrik, 2012). Based on these results, the humidity of each class was significantly higher than the standard. It should be noted that the measurement in the class was in the rainy season; therefore, the humidity should be rising at that moment. However, this shows that there is a need to dehumidify the environment by placing dehumidifiers, such as air conditioners or other electrical tools. Finally, the data of illuminance can be seen from Figure 5.

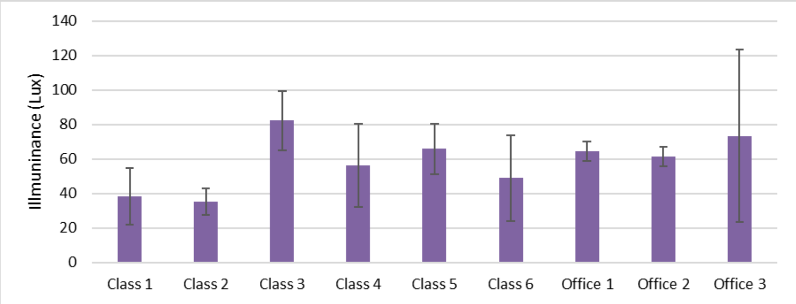

Figure 5. Graph of Illuminance Average Results in Class 1-6 and Office 1-3

The illuminance standard shows various ranges for each class. The results are 36.62 lux – 39.56 lux for Class 1, 33.3 lux – 38.02 lux for Class 2, 79,44 lux – 84.14 lux for Class 3, 55.84 lux – 57.4 lux for Class 4, 64.96 lux – 66.74 lux for Class 5, 46.8 lux – 50.52 lux for Class 6, 63.3 lux – 65.45 lux for Office 1, 60.44 lux – 62.76 lux for Office 2, 71.5 – 74.4 lux for Office 3. The precision of this measurement ranged from 71% – 93%. Compared to the standard in which for working spaces (such as class and office) the recommended illuminance is 300 lx, the results are below 1/3 of the standard (Standar Tingkat Pencahayaan SNI 6197 2020, 2020). As the measurement was taken without the presence of sunlight towards the building, it shows how dependent the use of natural lighting is for the classes and offices. Hence, it is also highly advisable to add more lighting, such as any type of lamp, to support the study process of SDN Rancagong 1 and 4.

It is crucial to consider several factors that might influence the measurement. First, no occupants were in the room during the measurements, so no heating contribution from people or any cooling effect from systems like fans were present. Second, airflow through the room is limited because the room was secured before measurements began. Third, environmental factors such as weather conditions may affect the measurement. Last but not least, a lack of sampling and location points could diminish accuracy and precision.

In addition to the data on the physical standards of comfort (thermal, lighting, and humidity), surveys were conducted to verify the findings qualitatively. Based on the survey, 70.4% of the respondents felt easy to perspire (sweaty), 55.5% felt relatively fine towards lighting, 40.1% felt relatively fine towards humidity, and 90.9% agreed to install renewable energy power plants to help them in electricity support for better comfort. In addition, based on interviews with staff (principal, guard, and teachers), it was confirmed that SDN Rancagong occupants felt the need for electrical tools such as air conditioners and lamps for the support of the study process. With these qualitative data, it is undeniable that more than 50% of the respondents who represented SDN Rancagong 1 and 4 occupants were dissatisfied with their current condition. As the occupants mostly consist of primary students (age 6-12), the urgency to add additional tools to help the study process is important.

Hence, some solutions that are recommended include installing electrical tools, using passive techniques, as well as utilizing renewable energy. Several electrical tools may consist of cooling systems (air conditioners and fans), dehumidifiers, lighting systems, and other similar supporting systems for studying processes. Note that the tools should be energy efficient. While passive techniques can be implemented by opening windows for natural ventilation and airflow to allow fresh air to circulate the class and cause thermal loss that is trapped inside the room. Moreover, renewable energy that can be considered is solar energy.

PVSyst Analysis

Based on observations and field surveys, the most suitable renewable energy technology is solar power. The potential for solar power for SDN Rancagong 1 and 4 is 4,560 kWh/m^2/Day (global horizontal irradiation), based on global solar atlas data. Considering this condition, it is best to use off-grid solar power plants that can serve as both the main and alternative power sources with electricity from government production (PLN) in case one is off. For a better approximation before installing the solar power plant, simulation using software can be performed to help the analysis and estimation of the energy, as well as to prevent ineffectiveness and losses. The analysis was initiated using additional sources, such as website-based software (Global Solar Atlas and Google Earth Pro). Based on latitude and longitude, SDN Rancagong 1 and 4 are located at -6.2833262047042275, 106.5832810379757. With this information, the direct normal irradiation is 923.8 kWh/m^2 per year, the optimum tilt of the PV Modules is 10 °, and the air temperature is 27.1°C. These data can be validated using the PVSyst metadata source (Figure 6), as shown below.

Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	132.4	100.9	472.2	36.6	0.000	396.0	396.0	1.000
February	139.9	114.7	542.7	175.0	0.000	357.7	357.7	1.000
March	153.2	141.3	663.4	255.4	0.000	396.0	396.0	1.000
April	145.6	145.6	683.8	282.3	0.000	383.2	383.2	1.000
May	143.7	157.5	741.5	339.8	0.000	396.0	396.0	1.000
June	140.8	160.7	758.7	359.0	0.000	383.2	383.2	1.000
July	146.5	163.8	775.0	366.0	0.000	396.0	396.0	1.000
August	152.8	159.7	752.0	342.8	0.000	396.0	396.0	1.000
September	154.0	146.8	692.5	299.1	0.000	383.2	383.2	1.000
October	171.0	146.9	695.7	283.9	0.000	396.0	396.0	1.000
December	141.1	106.2	502.8	85.9	0.000	396.0	396.0	1.000
Year	1766.7	1659.4	7829.3	2992.2	0.000	4662.5	4662.5	1.000
November	145.5	115.4	549.1	166.4	0.000	383.2	383.2	1.000

Legends

GlobHor	Global horizontal irradiation	E_User	Energy supplied to the user
GlobEff	Effective Global, corr. for IAM and shadings	E_Load	Energy need of the user (Load)
E_Avail	Available Solar Energy	SolFrac	Solar fraction (EUsed / ELoad)
EUnused	Unused energy (battery full)		
E_Miss	Missing energy		

Figure 6. PVSyst Meteo Data Source

Based on yearly global horizontal irradiation data, there is a difference between the data of 100 kWh/m^2. Finally, Google Earth (Figure 7) was used to estimate the maximum area for solar cell installation. With the preparation performed, the next step for the PVSyst simulation can proceed

Figure 7. SDN Rancagong 1 and 4 (Google Earth)

The area chosen for PVSyst was 28.6 m^2 for the module area and 16 m^2 for the cell area, with a total of 28 modules with Standard Test Conditions (STC) of 5.64 kWp. The parameters of the components of the solar power plant are detailed as follows:

1. PV Module = By Generic model AXNG1M200W with nominal power of 200 Wp with seven strings multiplied by four series. At the operating condition, the Pmpp 5.17 kWp, U mpp 75 V, and 1 mpp 69 A. The average power obtained was 12.8 kWh/Day.
2. Battery = By Generic model KBM216_14S 45Ah, with technology Lithium-ion, NMC with nominal 36 units in parallel, discharging minimum of State of Charge 10% and stored energy 74.8 kWh. The battery pack characteristics were 52 V, 1620 Ah (C10) nominal capacity, and 20°C.
3. Controller = DC-DC type with a temperature coefficient of-5 mV/°C/Elem, converter of Maxi and Euro coefficients (97/95%), and DC input voltage of 0 V.

Various components that integrate into the solar power plant were selected to determine the most feasible specifications. The components mentioned were chosen such that they did not exceed the receiving capacity of the inverter and for the temperature to not exceed the acceptable limit. Hence, the solar power plant simulation project using PVSyst resulted in the following:

1. System production = useful energy from solar by 4662.51 kWh/year, available solar energy by 7829.33 kWh/year, and excess/unused by 2992.18 kWh/year.
2. Loss of Load = time fraction 0%, missing energy 0 kWh/year, performance ratio PR 49%, and solar fraction SF 100%.

3. Battery aging (State of Wear) = cycles of SOW 98.4% and static SOW 90%.

Based on the analysis results, deprivation occurs within the system where the global horizontal irradiation of 1767 kWh/m^2 decreases according to the losses, which can be classified as follows:

1. Global incident in coll. Plane loss = -3.82%.
2. IAM factor on global = -2.34%.
3. Efficiency at STC = 19.60% that makes total of 9320 kWh.
4. PV loss due to irradiance level = -0.79%.
5. PV loss due to temperature = -8.39%.
6. Module quality loss = 0.24%.
7. Mismatch loss, modules, and string = -2.60%.
8. Ohmic wiring loss = -2.00%.
9. Loss with respect to the MPP running = -0.47%.
10. Unused energy (battery full) = -37.09%.
11. Converter loss during operation = -4.41%.
12. Converter loss due to power threshold = -0.29%.
13. Battery stored energy balance = 0.60%.
14. Battery efficiency loss = -1.83%.
15. Charge/Discharge current efficiency loss = -1.47%.
16. Battery self-discharge current = -1.09%.

It has a final power obtained about 4663 kWh. Therefore, when designing a solar power plant, some aspects that should be considered are:

1. Location and conditions (area, weather, temperature, plantation, and environment).
2. Solar power plant components and specifications (type and number of PV modules, batteries, controllers, inverters, and strings).
3. Loss calculations.

Thus, the best approximation is obtained. In this study, the power obtained can provide electricity for electrical tools as a means to support and improve the physical standards of comfort (thermal, lighting, and humidity). For determining the number of appliances to adhere to the standards, such as lamps for lighting system and air conditioning systems for thermal and humidity, a further field study must be carried out to confirm the overall conditions since many data such as exact room area and floor plan as well as electrical appliances specifications are not presented. In general, the determination of the lighting systems can be based on the following equation 1 (based on SNI 6197 2020) (Pranata & Salehuddin, 2024).

$$N = \frac{E\ average \times A}{F_i \times U_f \times M_f} \quad (1)$$

in which N is the number of lamps, E average is the illuminance standard (350 lux for class), A is area (m^2), Fi (lumen), Uf for utilization factor (usually by 0.5), and Mf for maintenance factor (usually by 0.6). These given parameters can estimate the requirement for the number of lamps which can be calculated after further field study. While for cooling system as a part of air conditioning, the estimation is based on equation (2).

$$Q = UA(T_O - T_i) + Q_{int} + Q_s + Q_{env} \quad (2)$$

in which Q is the cooling load (Watt), U is the overall heat transfer coefficient (W/m^2 K), A is the surface area of the building (m^2), To is the outside temperature (Celcius degree), Ti is the desired indoor temperature (Celsius degree), Qint is the internal heat gain (W), Qs is the solar heat gain (W), and Qenv is the ventilation gain or loss (W). These parameters can be further explored in SNI 03-6572-2001 which demand a complex structural assessment and calculation to determine the coolign load for the specified room.

IV. CONCLUSIONS

In conclusion, the study shows that SDN Rancagong 1 and 4 dissatisfied the physical standard of comfort based on SNI (thermal standard by 24°C – 27°C with the results of 30°C – 31°C, humidity standard by 55% – 56% with the results of 64% – 65%, and lighting standard not reaching one-third of 300 lx as the standard for working spaces). These findings are also strengthened by qualitative data that show that more than 50% of the occupants (from surveys) feel relatively uncomfortable towards the physical standards of comfort. With the importance of schools as a place for the new generation (i.e., students) to study knowledge for the purpose of building a better future, it is vital to have facilities that can support the study process. In cases where electricity use is minimal in these schools, immediate action is required. Hence, the use of renewable energy sources, such as solar power, can improve the situation. An analysis of solar power installation must first be performed using simulations to prevent inefficiency and losses. In this study, the use of PVSyst is pointed out with the results are useful available solar energy by 7829.33 kWh/year, performance ratio by 49%, solar fraction by 100%, cycles SOW 98.4% and static SOW 90% which include several losses such as system loss, PV loss, converter loss, and battery loss. However, the amount of power obtained may help in providing the need for electricity for SDN Rancagong 1 and 4, especially in electrical supply for tools such as air conditioners (for cooling rooms), lamps for lighting, and others to improve the physical standard of comfort. Hence, the proposed solar power plant can supply electricity to SDN Rancagong 1 and 4, enhancing the learning environment for students by meeting the physical comfort standards through the use of additional electrical appliances. Future research may consider more accurate parameters, the use of additional software for energy simulation to obtain a comparison as well as energy prediction analysis using Machine Learning for real-time data.

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