
DATASHEET-BASED EFFICIENCY COMPARISON ANALYSIS OF ALTERNATING CURRENT (AC) AND DIRECT CURRENT (DC) ELECTRICAL SYSTEMS

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ABSTRACT

In today's electrical infrastructure, a significant portion continues to depend on the AC (alternating current) system, necessitating energy conversion from DC (direct current) to AC during power generation and vice versa when reaching consumers. Nonetheless, as renewable energy sources and DC-based electronic devices gain popularity, the DC electrical system presents an attractive alternative. This research compares the energy efficiency between AC and DC electrical systems in school buildings. Through literature review and energy analysis in school buildings, the study found that the DC electrical system is significantly more efficient, achieving an efficiency rate of 89%. In contrast, the AC system only reaches 84%. The implications of this research provide valuable insights for implementing more efficient and sustainable electrical systems in buildings in the future.

Keywords: AC electrical systems, DC electrical systems, Inverter, Converter, Efficiency

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INTRODUCTION

As of the present moment, the prevailing method for generating electricity remains the utilization of Alternating Current (AC) as the primary electrical infrastructure (Gelani et al., 2017) (I. et al. T, 2018). PLN, the electricity service provider in Indonesia, generates electrical power in a centralized manner, which is then connected to the national grid (Kusmantoro et al., 2020). Most power generation facilities are situated in remote areas or outside major cities, close to energy sources (Avtar et al., 2019). This setup requires the electricity to be transmitted and distributed over considerable distances to reach the load centers or populated areas (Ali et al., 2017) (IESR, 2022). The current transmission and distribution system is the AC electrical system (Suripto, 2017).

On the other hand, there has been a notable shift in electricity utilization towards renewable energy sources such as solar, wind, hydropower, biomass, and geothermal energy (Ekadewi, 2022) (Citraningrum, 2019). Among these, solar energy is one of the most widely adopted options (Mayasari et al., 2022) (Mammadov et al., 2022). To harness solar energy effectively, solar panels play a crucial role in converting it into Direct Current (DC) electricity (Muner, 2021) (Muhammad, U. S Purwahyudi, 2021). Adopting renewable energy sources requires converters to convert DC electricity into AC electricity, enabling its transmission through the existing electrical system (Halim, 2020) (JE & WDC, 2012).

However, the current loads are often DC-based, such as LED lights, TVs, laptops, and smartphones (Warisanto, 2018) (Ploumpidou, 2017). Therefore, converters convert AC back into DC at the load side (Khalid, 2006) (Selvabharathi et al., 2020).

Incorporating renewable energy into the existing AC electrical system involves converting electricity from DC to AC at the generation side and subsequently converting it back from AC to DC at the load side (Hendrayana, 2017) (Liu et al., 2019). Conversely, in a DC electrical system, electricity sourced from the power generation undergoes only a single conversion from DC to DC before supplying the loads (Sireesha & Nagaraja, 2015).

Therefore, this research's primary objective is to compare the energy output generated by utilizing AC and DC electrical systems. The study will involve a case study conducted in a school building to analyze and evaluate the respective performances of both systems. The assumption is based on the loads of equipment used as parameters to obtain the energy produced from both energy sources. This study aims to compare the energy production in a school building using the AC and DC electrical systems. The analysis will be carried out over a five-day working period to assess the performance and efficiency of each system.

METHOD

The research method to compare the energy efficiency of AC electrical systems with DC electrical systems, with a case study of a school building, is illustrated by the flowchart in Figure 1.

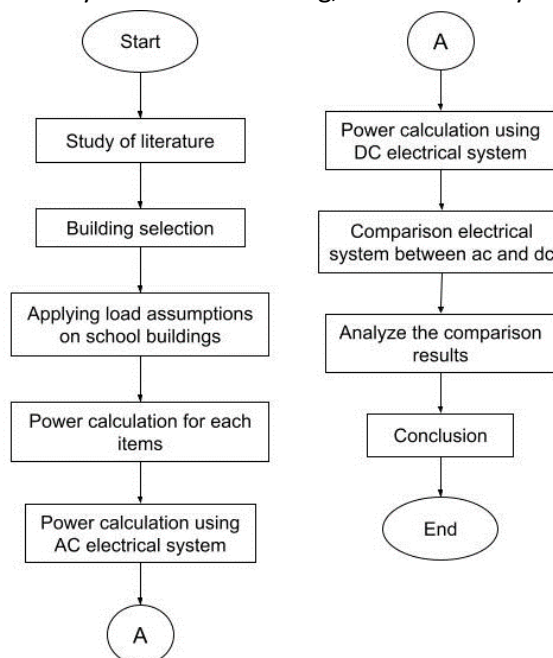


Figure 1. Flowchart of Research Methodology

In detail, the research is conducted based on the following methodology:

- 1) The methodology begins with a literature study, including relevant references on AC and DC electrical systems. Previous studies (Kusmantoro et al., 2020) have focused on the performance of electrical systems using photovoltaic systems, and other research (Wu & Hu, 2015) discusses

the development of technology in renewable energy sources. The difference in this research is that its outcome consists of comparing energy produced using AC and DC electrical systems.

- 2) Assumptions are made for the research location, which is the School Building. The assumptions used include the total area of the school and the number of classrooms in the school.
- 3) Assumptions are also made for the electronic appliances present in the school building and the determination of whether a converter/inverter is used for each electronic device. Additionally, information is gathered about the power consumption of the appliances with and without electrical power sources.
- 4) The collected data for the appliances is then used to perform energy analysis on the school building using AC electrical systems and DC electrical systems.
- 5) Finally, the results of the calculations are analyzed, comparing the AC electrical system and the DC electrical system.

Conventional Electrical System

Energy derived from nature, such as oil, natural gas, and coal, is generally used as a source of activity in daily life (Sanjaya & Dev, 2018). The AC distribution system is employed for transmitting electrical voltage with an alternating current system due to its advantages, including ease of operation, controllable AC voltage stability, and an AC distribution infrastructure (Rochman, 2012).

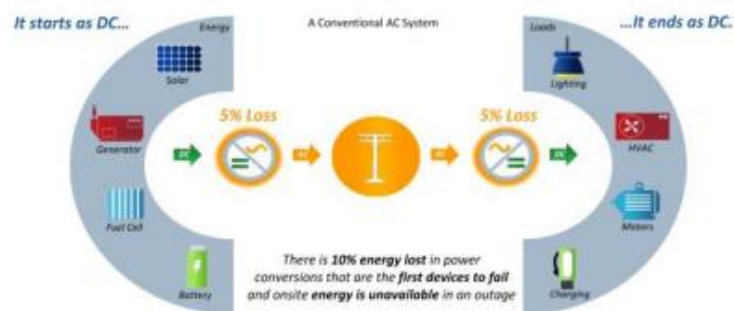


Figure 2. Illustration of Conventional AC System.

The illustration of AC distribution is shown in Figure 2, where the power generation on the generation side produces DC electric current, which needs to be converted into AC electric current for transmission and distribution. After being distributed to the load end, the electric current needs another conversion back to DC.

Converter

In this context, the implementation of converters transforms alternating current (AC) into direct current (DC) and vice versa. These converters facilitate the smooth integration and utilization of AC and DC electrical systems in the school building (Putri & Hamzah, 2017). AC to DC converters incorporating the Pulse Width Modulation (PWM) technique are extensively employed to achieve a consistent DC voltage. The efficiency and effectiveness of these AC-to-DC converters are contingent upon the input current and output voltage parameters. Proper regulation and control of these conditions are crucial for the reliable operation of the converters in converting AC power to stable DC voltage (Khalid, 2006). Various converter configurations exist, from two-stage AC to DC converters to DC to AC converters. Drive systems utilize single-phase to three-phase parallel single-phase rectifiers. Meanwhile, multilevel converters have the advantage of distributing voltage among

several sub-units. In contrast, parallel converters have the advantage of distributing current (Gautam et al., 2012).

Inverter

An inverter is an electronic apparatus crafted to convert direct current (DC) voltage into alternating current (AC) characterized by the intended amplitude and frequency. This capability is essential for various applications, such as powering AC-based electronic devices and integrating renewable energy sources into the grid, as they often generate DC power. The inverter's input voltage is commonly supplied by batteries, photovoltaic systems, accumulators, or alternative DC voltage sources (Azmi et al., 2017). Inverters can be distinguished based on their voltage control, such as Voltage-inverters (VIF), current-inverters (CIF), and inverters connected in various ways to the DC voltage (Apriani & Barlian, 2018).

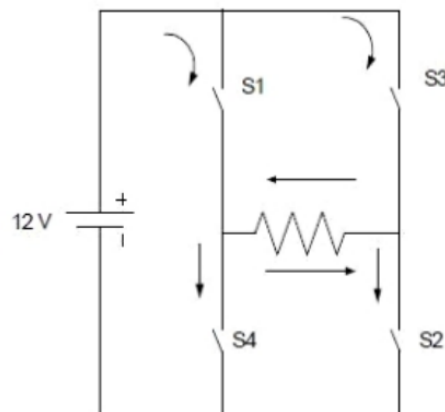


Figure 3. Illustration Of An Inverter [30]

Efficiency

Efficiency is the ratio of utilized energy to the energy required. In this research, two equations will be applied. Equation 1 represents the equation used to calculate the efficiency of using an AC electrical system.

$$\text{Efficiency} = \frac{x}{z} \times 100\% \quad (1)$$

In equation 1, the symbol "z" represents the definition of the total energy used by the AC electrical system during one week. On the other hand, "x" represents the total energy of the load without using any source.

Meanwhile, to calculate the efficiency using a DC electrical system, equation 2 is used.

$$\text{Efficiency} = \frac{x}{y} \times 100\% \quad (2)$$

Equation 2 introduces "x" as the total load energy without any source and "y" as the total load energy when employing the DC electrical system.

RESULTS AND DISCUSSION

In this research, a case study is conducted by considering a school building, which contains several rooms, as listed in Table 1 below.

Table 1. List Of Rooms in The School Building

Room	Total	Area
Class	18	1080m ²
Library	1	120m ²
Teacher room	1	120m ²
Principal room	1	30m ²
Counseling guidance room	1	30m ²
Canteen	1	60m ²
Multipurpose building	1	120m ²
OSIS Room	1	30m ²
Indoor Court	1	120m ²
Laboratory	1	240m ²
Clinic	1	60m ²
Toilet	8	340m ²

Based on the area of the rooms outlined in Table 1, this research applies an estimated load used in the school building, represented by one light bulb with an assumed area of 30m². The table below will detail the load data present in the school building.

Table 2. Load In The School Building

Load	Quantity	Watt
LED	80	18watt
Fan	21	50watt
AC	15	400watt
TV LED	1	70watt
Dispensers	2	300watt
Computer	35	300watt
Refrigerator	1	165watt

Energy Usage in the Building.

The energy source obtained from the AC electrical supply for the school building is assumed to be 725,000Wh (Watt-hours) for one week. This energy is drawn from the grid. It is estimated that this amount of energy is sufficient to accommodate all the loads present in the school building for one week, as the total energy consumed by the loads in the building amounts to approximately 587,770Wh for one week. The daily energy usage is presented in Table 3 and Table 4.

Table 3. List of Energy In One Day

Day	Air Conditioner	Fan	Computer
Monday	19.200Wh	7.550Wh	25.650Wh
Tuesday	34.200Wh	7.025Wh	72.450Wh
Wednesday	36.200Wh	6.900Wh	60.750Wh
Thursday	42.000Wh	6.250Wh	52.950Wh
Friday	36.200Wh	6.725Wh	72.450Wh

Table 4. List of Energy In One Day

Day	LED	TV	Fridge	Dispenser
Monday	9,504Wh	560Wh	3.960Wh	5.600Wh
Tuesday	10.467Wh	560Wh	3.960Wh	5.600Wh
Wednesday	10.287Wh	560Wh	3.960Wh	5.600Wh
Thursday	10.188Wh	560Wh	3.960Wh	5.600Wh

Day	LED	TV	Fridge	Dispenser
Friday	10.224Wh	560Wh	3.960Wh	5.600Wh

Table 5. Total Energy In One Day

Hari	Total
Monday	72.024Wh
Tuesday	134.262Wh
Wednesday	124.267Wh
Thursday	121.508Wh
Friday	135.719Wh
Total	587.770Wh

Table 5 lists the daily energy consumption from Monday to Friday, totaling 687,780Wh (Watt-hours).

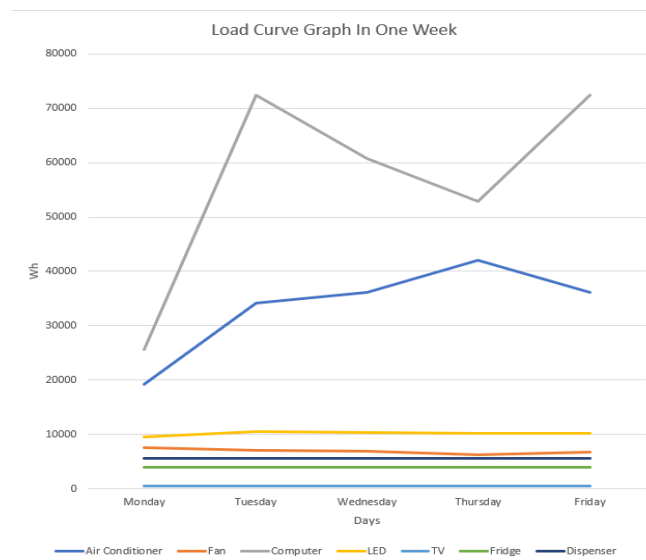


Figure 4. Load Curve of Load In 1 Week

Figure 4 represents the load curve graph for one week. For the next graph in this research, there are seven colors, which means:

- 1) Blue: AC load
- 2) Orange: fan
- 3) Grey: computer
- 4) Yellow: lamp
- 5) Light blue: tv
- 6) Green: refrigerator
- 7) Dark blue: dispenser

The graph shows the power of each load applied in the school building from Monday to Friday. It is evident that the usage of computers and air conditioners (AC) is relatively high due to their significant quantity and common usage, and their performance is also relatively high compared to other appliances. Therefore, computers and AC are the main contributors to the building's power demand.

The total number of AC units used is 35. Table 6 shows the locations where the AC units are active and the quantity and duration of their usage.

Table 6. List of RoomWith Air Conditioners

Room	Total	AC	Hours
Teacher's room	1	1	8
Library	1	2	8
Principal's room	1	1	8
Multipurpose building	1	4	<i>Tentative</i>
Science Lab.	4	16	<i>Tentative</i>
Computer Lab.	1	3	<i>Tentative</i>

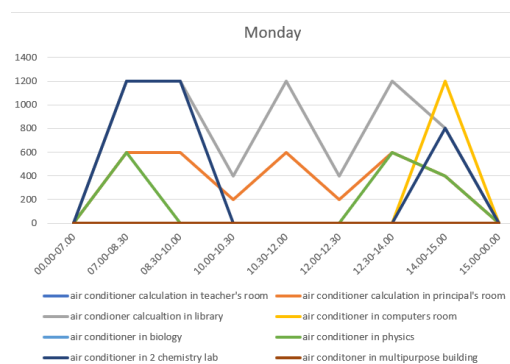


Figure 5. Load Curve Graph on Monday

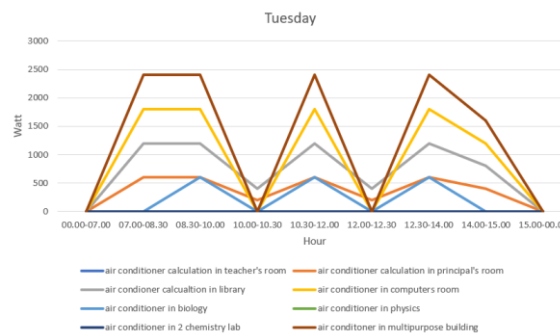


Figure 6. Load Curve Graph on Tuesday

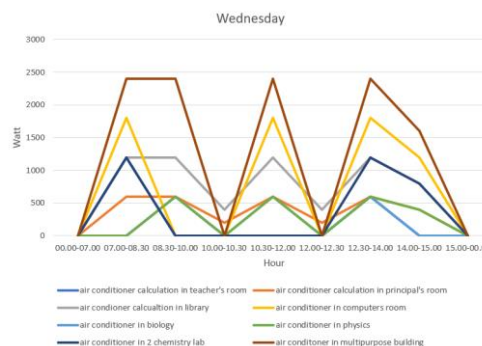


Figure 7. Load Curve Graph on Wednesday

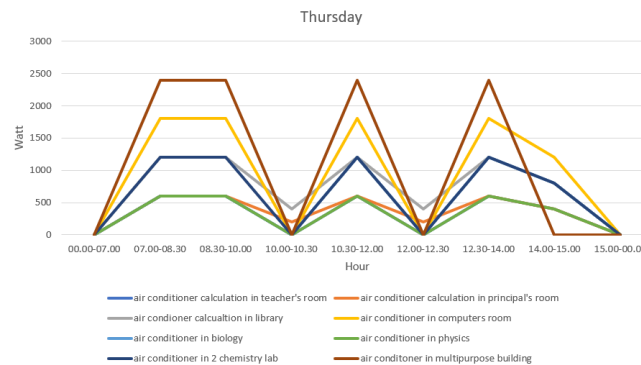


Figure 8. Load Curve Graph on Thursday

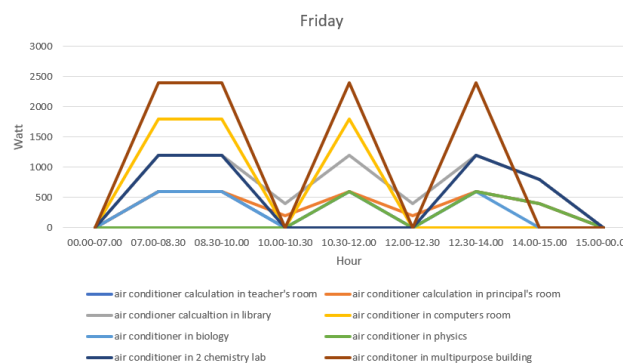


Figure 9. Load Curve Graph on Friday

There are a total of 35 computers used. Table 7 shows each location using a computer, along with the quantity and duration of their usage.

Table 7. List of Rooms with Computer

Room	Total	Hours
Library	8	7hours
Principal's room	1	8hours
Computer Lab	26	Tentative

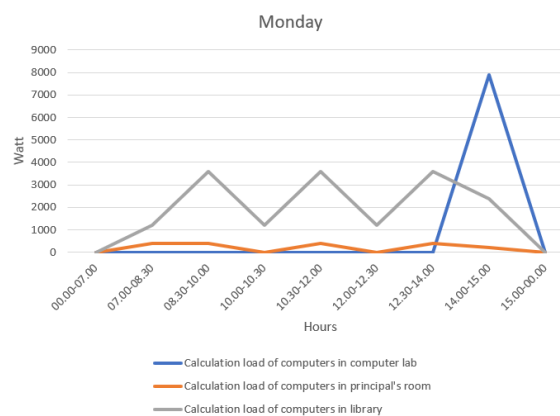


Figure 10. Load Curve of Computer on Monday

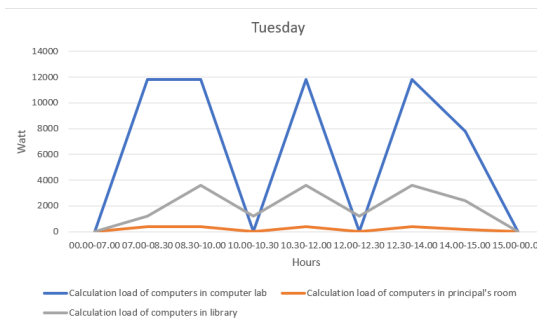


Figure 11. Load Curve of Computer on Tuesday

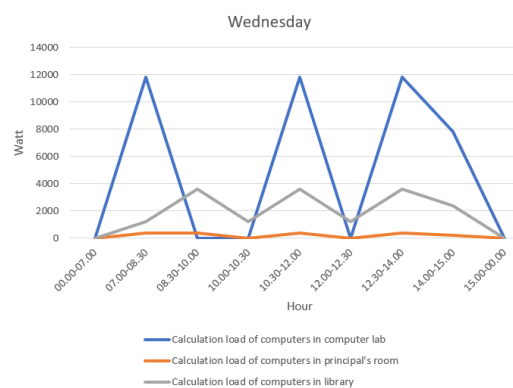


Figure 12. Load Curve of Computer on Wednesday

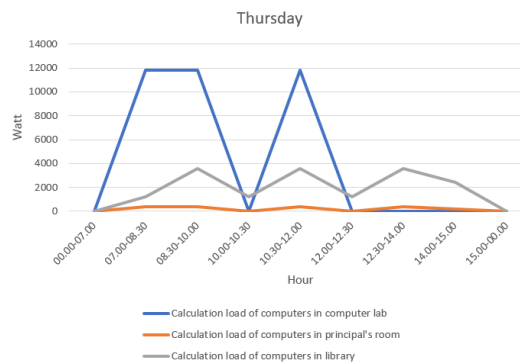


Figure 13. Load Curve of Computer on Thursday

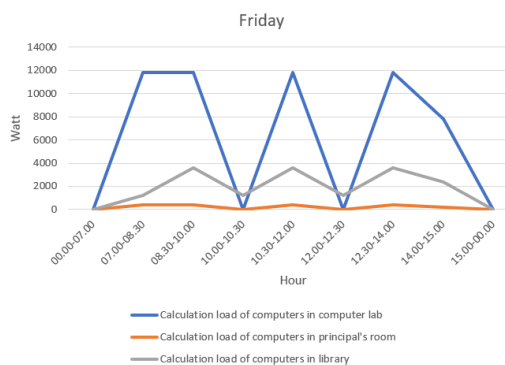


Figure 14. Load Curve of Computer on Friday

Energy Utilization in Buildings

Every load contained in the school building will be connected to a converter/inverter. Tables VIII and IX describe the converters/inverters in AC power systems. Efficiency is obtained from the converter/inverter datasheet used for each load.

Table 8. Converter/Inverter Data For AC Electrical Systems

Load	Converter/Inverter	Efficiency
AC	VSD	85%
Lamp	LED Driver	80%
TV	TV Box Converter	80%
Computer	Power supply	80%
Dispensers	Switching power supply	80%
Fan	AC/DC Power adapter	95%
Refrigerator	Panasonic compressor	82%

Table 9. Converter/Inverter Data For AC Electrical Systems

Load	Power Losses	Total Watt
AC	60W	460W
Lamp	3,6W	21,6W
TV	14W	84W
Computer	60W	360W
Dispensers	63W	413W
Fan	2,5W	52,5W
Refrigerator	29,7W	194,7W

Table 8 and 9 represents the power efficiency in the AC electrical system, which is assumed and adjusted for the datasheet for each load. Converter and inverter data are obtained from the specifications contained in each item. Efficiency is obtained from the specifications of the converter and inverter used. The lost power is obtained from the calculation of 100% minus the power efficiency, then multiplied by the item's power. The received power is obtained from the lost power plus the load power of each item.

Data is derived from the datasheet for each converter/inverter used in the DC electrical system, which is shown in Table 10 and Table 11.

Table 10. Converter/Inverter Data For DC Electrical Systems

Load	Converter/Inverter	Efficiency
AC	Boost Converter	94%
Lamp	LM2586 Converter	92%
TV	TV Box Converter	92%
Computer	Module power supply	85%
Dispensers	Boost buck converter	93%
Fan	Converter module	96%
Refrigerator	Refrigerator compressor	92%

Table 11. Converter/Inverter Data For DC Electrical Systems

Load	Power Losses	Total Watt
AC	32W	432W
Lamp	1,44W	19,44W
TV	5,6W	75,6W
Computer	45W	345W

Load	Power Losses	Total Watt
Dispensers	24,5W	374,5W
Fan	4W	54W
Refrigerator	13,2W	178,2W

Table 10 and Table 11 are the power efficiency in the DC electricity system, which is assumed and adjusted according to the datasheet for each load. Converter and inverter data are obtained from the specifications contained in each item. Efficiency is obtained from the specifications of the converter and inverter used. The lost power is obtained from the calculation of 100% minus the power efficiency and then multiplied by the item's power. The received power is obtained from the lost power plus the load power of each item.

AC Electrical System

The AC electrical system is visually depicted in the provided illustration in Figure 15.

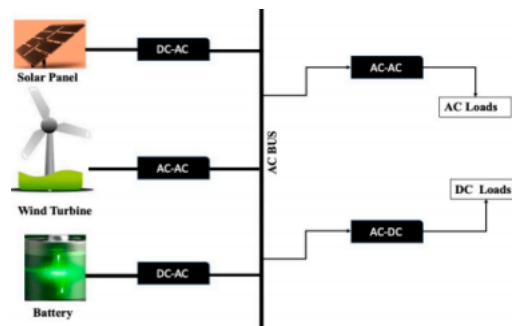


Figure 15. Illustration of AC Electrical System (Aemro et al., 2020)

The total load on the AC electrical system for one week will be calculated to get efficiency. Table 12 is a list of expenses for one week.

Table 12. Total Energy Of AC Electrical System In One Week

Day	Total
Monday	85.168,3Wh
Tuesday	165.199,45Wh
Wednesday	149.413,85Wh
Thursday	167.156,1Wh
Friday	137.904,1Wh
Total	704.841,8Wh

To obtain efficiency in the use of an AC electrical system, we can use equation 1.

$$Efisiensi = \frac{x}{z} \times 100\% \quad (1)$$

Applying equation 1, where x is the total energy used for one week in Table 5, and z is the total energy using the AC electrical system for one week in Table 12, an efficiency of 84% is obtained. This is directly proportional to the efficiency assumption of the load converter/inverter used in the AC power system.

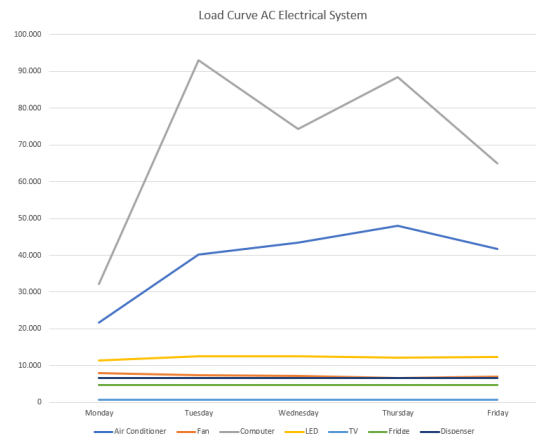


Figure 16. AC Electrical System Load Curve Graph

Figure 16 shows the load curve using an AC power system. It can be seen in the graph that the biggest electricity usage is computers and air conditioners. This is because these two loads require a large enough power to use them, and a large amount and frequent use makes these two loads the largest power load on the load usage list.

DC Electrical System

The illustration of the DC electrical system is depicted in Figure 17.

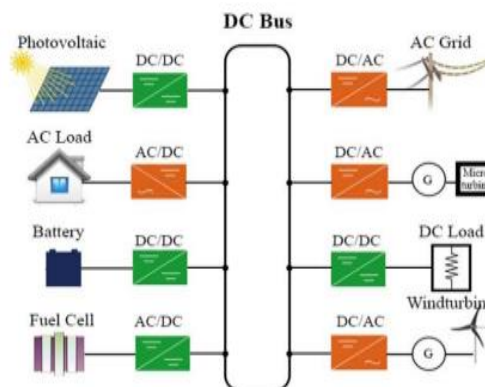


Figure 17. Illustration of the Circuit of DC Electrical System

In its utilization, the DC electrical system exhibits efficiency through converters/inverters. Table 13 shows the total energy consumed using the DC electrical system for one week.

Table 13. Total Energy of DC Electrical System In One Week.

Days	Total
Monday	80.292,92Wh
Tuesday	151.217,96Wh
Wednesday	141.269,72Wh
Thursday	158.503,64Wh
Friday	130.285,52Wh
Totals	661.569,76Wh

By applying equation (2), the efficiency value of using the DC electrical system can be calculated. The obtained efficiency value is 89%. The efficiency value of 88% is derived from comparing the total energy in Table 5 with the total energy in Table 13. This is due to the DC electrical

system's significant efficiency from each converter/inverter, resulting in minimal power losses in each load. Consequently, due to the relatively lower energy consumption over a week, the DC electrical system exhibits higher efficiency and improved performance compared to the AC electrical system.

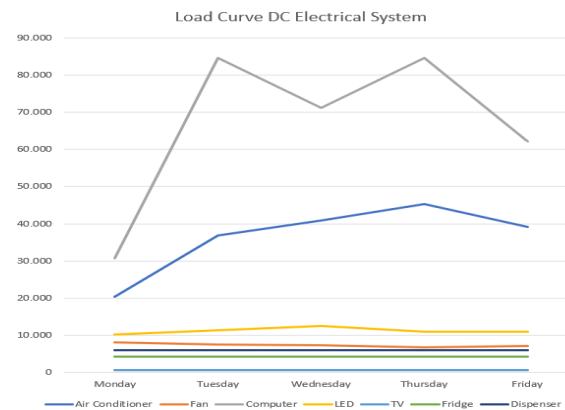


Figure 18. Illustration of the Loading Curve for the DC Electrical System.

Figure 18 shows the total load curve graph using the DC electrical system for one week. The graph above shows the power consumption of the loads utilized in the school building, operating under the DC electrical system, over one week. The energy consumption of computers and air conditioning is prominently depicted, revealing their higher electricity usage compared to other devices utilized in the school building during the one week under the DC electrical system. Additionally, it indicates that computers and AC are the components that cause a high power demand in the school building.

Efficiency

The calculation results showed that the AC electrical system achieved an efficiency of 84%. In comparison, the DC electrical system had an efficiency of 89%. The higher efficiency of the DC electrical system can be attributed to the enhanced performance of the converters or inverters employed within it, which outperforms the ones utilized in the AC electrical system. Furthermore, using a DC power source in the building leads to better efficiency when using DC-to-DC converters than AC-to-DC converters. The power losses that occur when using AC to DC converters significantly affect the power absorption by the loads. The efficiency comparison is depicted in the graph in Figure 19.

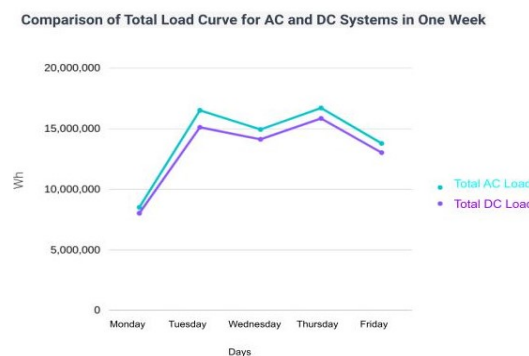


Figure 19. Load Curve Graph of the AC and DC Electrical Systems for One Week.

The DC electrical system's efficiency can also be observed from the graph in "Fig.19". The conspicuous display reveals a notable contrast in power consumption between the AC and DC electrical systems. The total energy consumption of the DC electrical system is lower than that of the AC electrical system. The disparity in power consumption arises from the higher power efficiency of individual loads in the DC electrical system, leading to lower power requirements for the loads compared to the AC electrical system.

CONCLUSION

The research conclusively proves the DC electrical system's remarkable efficiency, achieving an impressive 89%. In comparison, the AC electrical system falls behind with an efficiency of 84%. Using converters/inverters in the DC system contributes to its superior efficiency by minimizing power losses and reducing the power required by the loads. Computers and AC are the major power consumers in the school building, and their efficient usage significantly impacts the overall energy demand. Properly implemented, the DC electrical system proves to be a compelling choice for meeting energy needs in high-load environments like school buildings, offering better performance and energy utilization than the AC electrical system.

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