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Economic Calculations of Electricity Using AC System on Residential Load

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Abstract— The research in this final project discusses the economic calculation of electrical energy consumption in a 220 VAC system at a residential load on a type 54 house. The simulation of the AC system is carried out with ETAP 12.6 software. Simulation was done by making installations with residential loads with cables that have a length according to the distance to the loads. From the ETAP simulation, it can be seen the current and line resistance values on the report manager display so that the losses and efficiency of the two systems can also be known. Based on the results of simulations and calculations, the total value of the losses that occur in the 220 VAC system was so small that it looks like 0 watts. This happens because the simulation results were shown in kilowatt at the ETAP.

Keywords: economic calculations, electricity, 220 VAC system, residential.

1. Introduction

The electric power system used in Indonesia today, starting from generators, transmission lines and distribution lines to the load, is a collection of power centers and substations (load centers) which are connected to each other by a transmission network so that it is an interconnection unit and generally uses alternating current (AC) power system. AC electricity has several advantages and disadvantages. The advantages of AC power, among others, are suitable as a centralized system, to transmit over long distances, it does not require large cables, and there are many available AC applications. While the drawbacks, among others, cannot be stored, in its application there is a lot of energy lost, and it is dangerous.

2. Literature Review

Electric power is generated in power centers such as hydroelectric power plants, steam power plants, gas power plants, geothermal power plants, and diesel power plants then channeled through transmission lines after the voltage is first increased by a step-up transformer in the power center [1]. After the electric power is distributed through the transmission line, then the voltage is lowered through a step-down transformer which is usually at the substations into a medium voltage or also known as the primary distribution voltage. The primary distribution voltage used by PLN is usually 20 kV, 12 kV, and 6 kV. After the electricity is distributed through the primary distribution network, then the voltage

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is lowered in distribution substations to a low voltage with a voltage of 380/220 V or 220/270 V, then routed through a low-voltage network. Furthermore, it is distributed to the homes of PLN customers (consumers) through house connections [2] [3].

After electric power goes through the medium voltage network, low voltage network, and home connection, then the next electric power goes through a power limiter and a KWH meter. After going through the KWH meter, the electric power then enters the home installation, which is the customer's installation. In customer installations, electric power directly enters the customer's electrical equipment, such as lamps, irons, refrigerators, radios, televisions and others. It is understandable that the size of the efficiency and consumption of electric power is determined entirely by the customer, which depends on how the customer uses the electrical equipment and then PLN follows the electricity needs of the customers, this is in the sense of adjusting the electrical power generated from time to time [4].

For the purposes of providing electricity to customers, various electrical equipment is needed. These various electrical equipment are connected to each other and have an interrelationship and as a whole form an electric power system. What is meant by an electric power system here is a collection of electrical centers and substations (load centers) which are connected to each other by a transmission network so that it is an interconnection unit [5].

The load of the electric power system is the consumption of electricity from electricity customers. Therefore, the magnitude of the load and its changes depend on the customer's need for electric power. In general, distribution channels serve the load by being divided into several sectors, including the household sector, industrial sector, business sector and commercial sector [3].

One form of energy is electrical energy which is often used by households. The demand for household electrical energy is based on the basic demand for the services of electrical appliances (appliances) in the household. The household sector experienced a significant increase at night because the use of electrical equipment occurred at night, while during the day it decreased. In the household sector customers themselves are divided into several groups including groups R1, R2, and R3. For R1 customers the power used starts from 450 VA to 2200 VA, in the R1 group with 900 VA power there are differences, namely subsidies and not subsidies. For R2 customers the power used is 3500 VA – 5500 VA, while for R3 customers the power used is 6600 VA and above. The load has resistive, inductive, and capacitive, properties have an impact on the electrical system, namely the load factor. The greater the load factor, the better the electrical system and vice versa. Therefore, when an electrical system has a low load factor, large reactive power, PLN will provide its own tariff so that load factor improvements are needed [6].

The electricity supplied to the customer is required for the use of various household electrical appliances. These various electrical equipment are connected to each other which have interrelationships and as a whole form an electric power system. The electric power system used in Indonesia today, starting from generators, transmission lines and distribution lines to the load, is a collection of power centers and substations (load centers) which are connected to each other by a transmission network so that it is an interconnection unit and generally uses alternating current (AC) power system. AC electricity has several advantages and disadvantages [7].

The advantages of AC power, among others, are suitable as a centralized system, to transmit over long distances, it does not require large cables, and there are many available AC applications. While the drawbacks, among others, cannot be stored, in its application there is a lot of energy lost, and it is dangerous [8].

With the rapid development of technology, the demand for electricity on the load side also continues to increase, so it is necessary to adjust the technology of the electric power system. The majority of AC electrical systems have several shortcomings, including the longer the transmission line and distribution line, the greater the losses and voltage drops and the power factor value or the ratio between active power and apparent power is low resulting in increased load current and high temperature in the system, the power factor value is influenced by inductive load and capacitive load. While the AC system in power distribution and use on the load side [9].

For many years, fossil energy (petroleum, natural gas, and coal) has been the main energy source to meet the world's energy needs. However, this energy source is an energy source that will run out and cannot be renewed. If there is no good management and savings, it will decrease day by day and it is possible that it will run out.

The electric power system used in Indonesia today, starting from generators, transmission lines and distribution lines to the load, is a collection of power centers and substations (load centers) which are connected to each other by a transmission network so that it is an interconnection unit and generally uses AC power system. AC electricity has several advantages and disadvantages. The advantages of AC power, among others, are suitable as a centralized system, to transmit over long distances, it does not require large cables, and there are many available AC applications. While the drawbacks, among others, cannot be stored, in its application a lot of energy is lost, and it is dangerous [10].

In the AC system the presence of reactive power also increases the power loss of the system. This is due to the inductance in the line which affects the power factor. The larger the inductance in the line, the lower the power factor. This low power factor causes an increase in current to meet the same amount of power. As the current increases, the power loss in the line also increases. At a load supplied with an AC system, for a single phase load, the power loss calculation is as follows [11]:

$$P_{loss} = 2\frac{R}{cos\varphi}\frac{P^2}{E^2} \tag{1}$$

Meanwhile, if the supplied load is a three-phase load, the power loss calculation uses the equation:

$$P_{loss} = 2\frac{R}{3cos\varphi}\frac{P^2}{E^2} \tag{2}$$

where:

P_{loss}	: power loss (watts)
R	: conductor wire reactance (Ω)
$cos\varphi$	: power factor
P	: power consumption by load (watts)
E	: rms voltage (phase to ground)

2.1 AC Distribution

Alternating current (AC) distribution system is the distribution of electric power with alternating current and voltage. This system was first developed by George Westinghouse with a number of patents from Nikola Tesla. AC distribution systems are currently widely used to meet the needs of electrical energy and have been widely applied for more than 100 years. This system has several advantages, including [12]:

a) Easy process of transforming voltage from one level to another by using a transformer.
b) The stability of the AC voltage can be controlled from the active power through the reactive power setting.
c) Suitable for loads in the form of alternating current motors (AC motors). In AC motors, such as synchronous motors, the stator part requires a three-phase voltage supply to produce a rotating magnetic field in the stator which then rotates the stator magnetic field to rotate the rotor.

d) The protection system in the AC distribution system is more developed than the protection system in the DC distribution system.
e) Problems in the field of protection from the past until now have resulted in various developments in the field of protection in the AC distribution system

In addition to the advantages, the AC system also has disadvantages including:
a) Because of the frequency, frequency instability can occur due to certain factors, such as load fluctuations that make the frequency value not constant
b) Synchronization of generators for parallelized generators is required so that there are conditions that need to be met such as the same voltage, the same frequency as the two generators, the same phase sequence and the same phase angle.
c) In the AC system, there is a voltage sag and voltage swell condition that can affect power quality. Voltage sag is a condition where the voltage drops below 90% of the nominal voltage value, while voltage swell is a condition where the voltage rises above 110% of the nominal voltage value. Voltage sag can be caused by a generator that is off (trip) or it can be a large load that enters the system simultaneously, while voltage swell can be caused by a large load that is lost simultaneously. In addition to voltage sag and voltage swell, there are other conditions in the AC system that can affect power quality such as interruption, noise, flicker.
d) In a three-phase system, three-phase imbalance may occur. This three-phase imbalance can be caused by the load impedance of each phase which is not identical
e) Harmonic distortion can occur which affects the quality of electric power. This can be caused by equipment such as adjustable speed drives or loads such as arc furnaces, arc welders, etc. Ideally, the alternating voltage/current wave is sinusoidal in shape but, due to the presence of harmonic frequencies, there is a summation between the harmonic frequency waves and the fundamental frequency wave which then results in harmonic distortion where the wave is no longer sinusoidal.
f) The power factor value is usually less than 1, so that not all of the total power (apparent power) generated by the generator becomes used power (active power).

2.2 Efficiency

In essence, it is known that energy efficiency is part of energy conservation. In the national energy policy, it is stated that energy conservation is a systematic, planned and integrated effort to conserve domestic energy resources and increase the efficiency of their utilization. In Indonesia, this energy conservation effort is very important given the large gap between the demand side and the supply side, so that it is widely practiced. Energy audits are recommended to be carried out in buildings such as office buildings, schools, hotels, apartments, shopping centers and hospitals [9].

2.3 Voltage Drop

The voltage drop can be higher when using progressively lower voltages in the distribution system, poor power factor, single-phase circuits, and unbalanced circuits. The voltage drop can be reduced in several ways including [4][13]:

1. Increasing the power factor, one of which is by adding a capacitor;
2. Enlarge conductor size; and
3. Balancing the network.

The voltage drop has a value limit based on certain standards. Based on the National Electrical Code (NEC), the recommended maximum voltage drop limit is 5% of the nominal voltage [6].

2.4. Power Factor

Power factor improvement is to correct the difference between the active power angle and the apparent power used in an AC electrical system circuit or the phase angle difference between the voltage and current values, usually expressed in cos φ. The power factor value has a range from 0 to 1, the closer to 1, the better the power factor value. Then to calculate the power factor value can be done by dividing the active power (P) by the apparent power (S). The power factor is divided into two, namely the lagging power factor and the leading power factor [14][15].

2.5 ETAP

ETAP is one of the software that is commonly used as an electric power system simulation. Design and analysis simulations that are usually carried out using the ETAP application are such as power flow analysis, short circuit analysis, harmonic power system analysis, motor starting analysis, simulation of transient stability testing and others [11].

In a simulation or design of an electric power system, it is necessary to have the ability to convert a real electrical system into a model which is usually called a one-line diagram, then complete with real data in the field, for example, the conductor data used by the motor nameplate and so on [16].

3. Method

3.1 System Design

The research design was made in the following order:

1. Study of literature;
2. Determination of the electrical installation system of a type 54 residential house;
3. Design of the installation system on the ETAP software both the AC system;
4. Running programs;
5. Report the results of the simulation of the power flow of both the AC system;
6. Calculation of power losses in both AC systems; and
7. Calculation of the efficiency of the two AC systems.

3.2 House Plans and Types

The house plan and wiring installation in a house type 54 in Figure 1 is the object of research that will be carried out. This existing wiring installation will be assembled and simulated on the ETAP software.

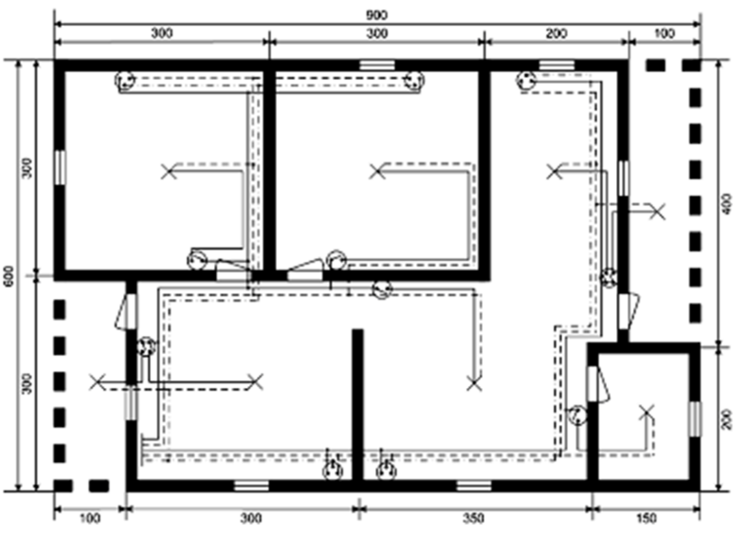

Figure 1. Simple electrical installation for a residential house with a building area of 54 m^2.

In order for this research to be completed properly, the data used are definite (real). Residential load data in this test are household electrical equipment used at home of type 54 m^2. The load profile of that type 54 house was presented in Table 1.

Table 1. Residential Electrical Load Profile (House Type 54)

No.	Load Name	Load Power (watt)	Hours of Use per day (h)	Energy Consumption (Wh)
1	Socket Living Room 1 (Smartphones 1 and 2)	10	4	40
2	Socket Living Room 2 (Smartphones 3 and 4)	10	4	40
3	Central Room 1 (Television) socket	59	5	295
4	Central Room 2 (Dispenser)	250	1	250
		10	17	170
5	Socket Dining Room 1 (Fridge)	60	2	120
		15	22	330
6	Dining Room 2 (Rice Cooker)	350	0.5	175
		65	3	195
7	Bedroom 1 socket (fan)	40	5	200
8	Bedroom 1 socket (reserve)	0	0	0
9	Socket for bedroom 2 (fan)	40	5	200
10	Socket for bedroom 2 (reserve)	0	0	0
11	Porch Light	5	10	50
12	Living Room Lights	12	4	48
13	Living Room Lights	18	6	108
14	Bedroom Lamp 1	8	4	32
15	Bedroom Lamp 2	8	4	32
16	Dining Room Lights	12	3	36
17	Kitchen Lights	12	4	48
18	Bathroom Lights	5	3	15
Total Energy Consumption / day				2384
Total Energy Consumption / day + 20%				2860.8

4. Results and Discussion

4.1 Installation System Design on ETAP Software Good AC System

The design carried out on the AC system in the ETAP software is adjusted to the layout of the house type 54 house. All loads and cables used are in AC format. In the AC system, the power supply source for residential loads is obtained directly from the 220 volts AC voltage on the PLN grid. Design of the installation of the ETAP software on the AC system was presented in Figure 2.

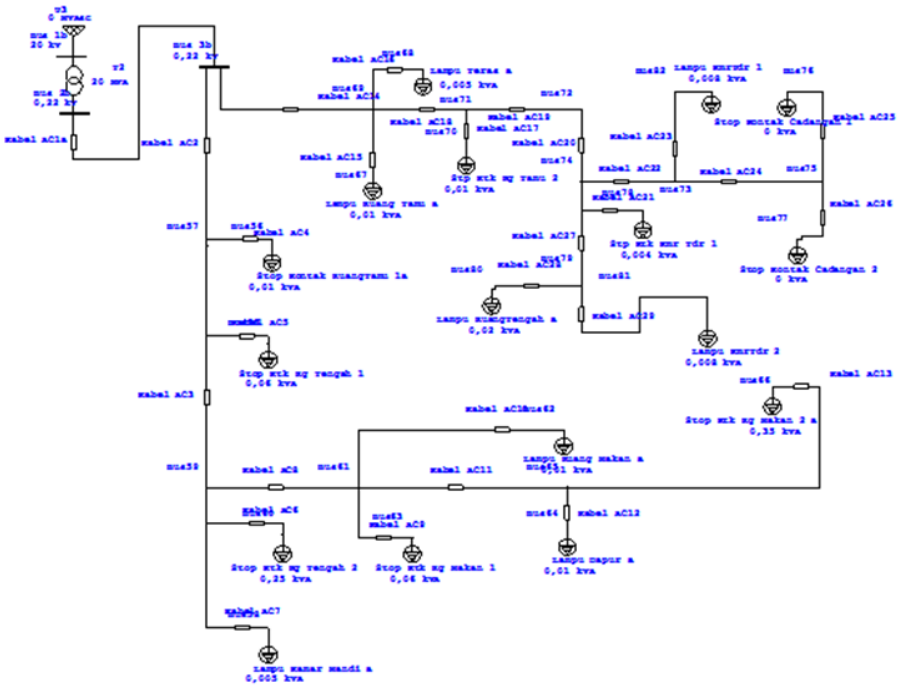

Figure 2. Design of the installation of the ETAP software on the AC system

4.2 Installation Fee

We can take a simple approach or assume that the installation costs for electricity consumption by PLN and with Solar Cells are calculated the same. Comparison of the cost of new installations between PLN electricity and PLTS as follow:

PLN
Connection Fee + SLO + Stamp = (Rp)
1,218,000 + 95,000 + 6,000 = 1,319,000

4.2 Variable Cost

PLN electricity
Abonemen Fee = 1,300 VA / 1,000 x Rp 1,467 = Rp 1,907.1
Amount of Total kWh Fee = Total kWh × Rp 1,467
= 71.88 kWh × Rp 1,467 = Rp 105,447.96
Amount of PLN Bill = Total kWh + PPJU + Stamp Fee + Administration + Subscription
= Total kWh × (1 + 2.4%) + Stamp Fee + Administration Fee + Subscription
= Rp 105,447.96 + (Rp 105,447.96 × 1,024) + Rp 6,000 + Rp 2,500 + Rp 1,907.1
= Rp 223,833.771 average per month
The calculation cost of PLN electricity for 60 years was presented in Table 2.

Table 2. Calculation cost of PLN electricity

No.	Year	Fee with PLN (Rp)
1	0	Rp 1,319,000
2	5	Rp 15,020,326
3	10	Rp 29,420,558
4	15	Rp 44,153,857
5	20	Rp 60,060.672
6	25	Rp 76,778,894
7	30	Rp 94,349,913
8	35	Rp 112,817,231
9	40	Rp 132.226.567
10	45	Rp 152,625,975
11	50	Rp 174,065,957
12	55	Rp 196,599,595
13	60	Rp 220,282,674

4. Conclusion

Based on the results of the ETAP simulation and the calculations that have been carried out, it can be concluded as follows. In designing and assembling electrical installations using the ETAP application for residential homes, the AC system must pay attention to all the components used, all the components used are different between the AC system and other systems even though the picture is the same. Furthermore, in carrying out the program one must also pay attention to the system being run, whether it is the AC system or other systems. The results of the power flow program on ETAP can be seen from the resulting report. No need to measure it, we can know how much power losses occur, how much voltage occurs on each bus. The average financing for using PLN electricity for type 54 residential houses is Rp 223,833.771, and if it is calculated for up to 60 years, the consumer will spend Rp 220,282,674.

References

[1] S. S. Wibowo, *Analisa Sistem Tenaga: Analisa Sistem Tenaga*, vol. 1. UPT Percetakan dan Penerbitan Polinema, 2018.

[2] A. Hasibuan, K. Kartika, S. Mahfudz, and M. Daud, "Network Reconfiguration of 20 kV Sample Connection Substance LG-04 Lhokseumawe City Using Digsilent Power Factory Software Simulation 15.1," *Int. J. Adv. Data Inf. Syst.*, vol. 3, no. 1, pp. 20–29, 2022.

[3] A. Hasibuan, S. Masri, and W. Othman, "Effect of distributed generation installation on power loss using genetic algorithm method," in *IOP Conference Series: Materials Science and Engineering*, 2018, vol. 308, no. 1, p. 12034.

[4] A. Hasibuan, A. Bintoro, S. Salahuddin, and R. D. Meutia, "Reliability Distribution System on Load Break Switch Addition at PT. PLN (PERSERO) ULP Langsa City Using RIA-SECTION Technique Combined Method on ETAP 14.1. 0," *Andalasian Int. J. Appl. Sci. Eng. Technol.*, vol. 2, no. 2, pp. 57–64, 2022.

[5] A. Hasibuan, M. Isa, M. I. Yusoff, S. R. A. Rahim, and I. M. A. Nrartha, "Effect of installation

of distributed generation at different points in the distribution system on voltage drops and power losses," in *AIP Conference Proceedings*, 2021, vol. 2339, no. 1, p. 20134.
[6] S. Ramadoni, "Buku ajar transmisi dan distribusi tenaga listrik," *Penerbit LP3M Univ. Muhamadiyah Yogyakarta*, 2016.
[7] M. Wijaya, "Dasar-Dasar Mesin Listrik," *Jakarta: Djambatan*, 2001.
[8] Z. Mohammed, H. Hizam, and C. Gomes, "Analysis of lightning transient effects on hybrid renewable energy sources," in *2018 34th International Conference on Lightning Protection (ICLP)*, 2018, pp. 1–7.
[9] D. Warisanto, J. T. Elektro, F. T. Industri, and U. I. Indonesia, "Pada Beban Residensial Menggunakan Software," 2018.
[10] R. T. Jurnal, "Studi Penyimpanan Energi Pada Baterai Plts," *Energi \& Kelistrikan*, vol. 9, no. 2, pp. 120–125, 2017.
[11] A. Hasibuan, F. Dani, I. M. A. Nrartha, and others, "Simulation and Analysis of Distributed Generation Installation on a 20 kV Distribution System Using ETAP 19.0," *Bull. Comput. Sci. Electr. Eng.*, vol. 3, no. 1, pp. 18–29, 2022.
[12] O. D. Montoya and W. Gil-González, "On the numerical analysis based on successive approximations for power flow problems in AC distribution systems," *Electr. Power Syst. Res.*, vol. 187, p. 106454, 2020.
[13] K. Techakittiroj and V. Wongpaibool, "Co-existance between AC-distribution and DC-distribution: in the view of appliances," in *2009 Second International Conference on Computer and Electrical Engineering*, 2009, vol. 1, pp. 421–425.
[14] A. Hasibuan, B. Badrina, and A. Z. Hasibuan, "SIMULASI ANALISIS ALIRAN DAYA SUB SISTEM ACEH 150 KV MENGGUNAKAN SOFTWARE POWERWORLD SIMULATOR," *J. Electr. Syst. Control Eng.*, vol. 3, no. 1, pp. 42–52, 2019.
[15] A. K. Al Bahar, "Analisa Pengaruh Kapasitor Bank Terhadap Faktor Daya Gedung TI BRI Ragunan," *J. ELEKTRO*, vol. 6, no. 1, 2018.
[16] B. F. Risjayanto and T. Wrahatnolo, "Optimal Capacitor Placement (OCP) Pada Sistem Jaringan Distribusi 20 Kv Menggunakan ETAP," *J. Tek. Elektro*, vol. 8, no. 1, 2019.