Electricity Savings Using Passive Filters

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Abstract. This study aims to provide knowledge in order to save electricity consumption. The use of electrical energy is recorded at KWH meters. Saving electricity means limiting the use of electrical energy according to need. The use of electrical energy is based on the use of electrical power. Technically, this dimmer serves to regulate the use of electrical power. Some electrical equipment has been equipped with dimmers to regulate the operation of the equipment in accordance with the user’s want, yet there are still many electrical equipment that is not equipped with dimmers. This is a problem in the efforts to save electricity. The method used in this study is applying passive components in electricity such as inductors, capacitors and resistors. These passive components are arranged to be used as filter circuits. With a 21 mH inductor with an air core, Farad's 12.5 micro capacitor, and 4.7 ohm resistor can be made as a passive filter that is installed before electric loads. The use of this filter circuit can save the use of electricity up to 15% at a load current of 2 amperes. Thus, electricity bill payments can be reduced by up to 15%. In the future, this research can be continued to improve the efficiency of electricity consumption by modifying passive filters.

1. Introduction
The most common energy used by Balinese people in general is electricity. Almost every residential house in Bali has an electrical installation installed. This electrical energy is used for lighting and turning on electrical loads such as TVs, rice cookers, water pumps, air conditioners, and other household appliances. Conceptually, the use of these electrical loads requires active power and reactive power. However, for household electricity customers, the use of reactive power because turning on the electricity loads is not charged by PLN. Electricity customers only pay for their active power usage. Every month, the customers must pay the amount of active power that is measured by kWh meter.

Before the increase in basic electricity rates, the customers almost never complain about the amount of payment paid to PLN. Yet lately, with the increase in basic electricity rates, many customers have complained many times because they pay a lot of electricity bills. The advancement of science and technology causes many household appliances require more electrical energy. This condition also affect the increase of electricity payments to PLN.

The use of various household appliances causes bad quality of the voltage and its flows within the equipment. In this case, the kWh meters will record the electricity usage higher and give impact to the increase of the payment. A lot of electricity bills are usually due to the use of air conditioning and building equipment caused by the atmosphere of a hot environment [5]. The bad quality of voltage and electric current can be fixed by filtering them through the use of inductors, capacitors and autotrafo slides. Therefore, applying these components to an electrical equipment is needed by customers so that
the kWh meter records less usage of electricity. Yet, actually there is no public market which sells equipment with that kind of functions. The electrical equipment applies a passive filter to electrical installations in the household.

2. Electric Power Triangle

Electricity is the magnitude of the rate of electrical energy that occurs in an electrical circuit. In international units the electrical power is $W$ (Watt) which states the amount of effort carried out by the voltage source to drain the electric current per unit of time $J / s$ (Joules / second). There are 3 types of electrical power, namely apparent or total power ($S$), real power ($P$), and reactive power ($Q$). The apparent power or total power ($S$), is the result of the multiplication between the effective voltage (root-mean-square) and the effective current (root-mean-square). This theory is often used for power factor compensation [2].

$$S = V_{RMS} \times I_{RMS}$$

Effective voltage or RMS is a voltage that can be measured using a volt meter. The RMS voltage ($V_{RMS}$) is the AC voltage value which will produce the same power as the equivalent DC electric power at the same resistive load. This definition also applies to RMS currents. 220 volts of our home's voltage is the RMS voltage (effective voltage). Simply put, 220 volts is 0.707 parts of the maximum sinusoidal AC voltage. Here is a simple formula for calculating RMS voltage and RMS current:

$$V_{RMS} = \frac{V_{MAX}}{\sqrt{2}}, \quad I_{RMS} = \frac{I_{MAX}}{\sqrt{2}}$$

Where $V_{MAX}$ and $I_{MAX}$ are voltage and electric current values at the highest point on the graph of sinusoidal wave AC power.

![RMS Voltage Value](Source: Indonesian Technology Article)

Real power ($P$) is the power required by resistive loads. Real power shows the flow of electrical energy from power plants to the load network to be converted into other energy. For example, the real power used to power an electric stove. Electrical energy flowing from the network and into the electric stove, is converted into heat energy by the stove's heating element. Electrical power in AC electric current, is formulated as an effective electric current, effective voltage, and power factor ($\cos \varphi$)

$$P = V_{RMS} \times I_{RMS} \cos \varphi$$

Reactive power is the power needed for the formation of a magnetic field or the power generated by an inductive load. The unit of reactive power is VAR (Reactive Amp Amper). To save reactive power can be done by installing a capacitor in a circuit that has an inductive load. The same thing is often done in factories that use motorcycles using loads of electric motors. Reactive power equation:

$$Q = V_{RMS} \times I_{RMS} \sin \varphi$$
Table 1. Correlation of Power, Real Power, and Reactive Power

| Daya Semu (S)       | Daya Nyata (P)       | Daya Reaktif (Q)       |
|---------------------|----------------------|------------------------|
| \( S^2 = P^2 + Q^2 \) | \( P^2 = S^2 - Q^2 \) | \( Q^2 = S^2 + P^2 \) |
| \( S = \sqrt{P^2 + Q^2} \) | \( P = \sqrt{S^2 - Q^2} \) | \( Q = \sqrt{S^2 - P^2} \) |
| \( S = V_{RMS} I_{RMS} \) | \( P = V_{RMS} I_{RMS} \cos \phi \) | \( Q = V_{RMS} I_{RMS} \sin \phi \) |

Based on Figure 2, S and Q power consumption savings can be done by improving the power factor (\( \cos \phi \)). This is done by reducing the phase angle between voltage and current (\( \phi \)). One way to improve the power factor is to install capacitive compensation using capacitors on the network. Through adjusting phase angle (\( \phi \)), the use of reactive power can be reduced [3]. The capacitor is an electrical component that actually produces reactive power on the network where it is connected. In an inductive network with a power triangle as shown in Figure 3, if the capacitor is installed, the reactive power that must be provided by the source will be reduced by (which is the reactive power derived from the capacitor). Because active power does not change while reactive power decreases, then from the source point of view, the new power triangle is obtained; shown in Figure 3 orange line. It is seen that the angle decreases due to the installation of the capacitor so that the network power factor will rise. The capacitor is one filter and the addition of a filter to the system can improve the quality of electrical power [4]. Nonlinear loads create a series of adverse effects on electrical networks such as three-phase imbalances from the power grid, negative sequence currents, high-order harmonics, voltage distortion, flicker and low power factors [1].

3. Development Method
This research is a type of development research by adapting Borg & Gall’s development model (Figure 4). Because of the limitations of the material, time and ability of the researcher, in this study the stages will be carried out until the seventh stage.
The object of this research is the electrical equipment in the form of Voltage Stabilizer Plus and the subject of the research is the household electrical system.

Based on the development model in Figure 4, the detailed steps of the research are as follows: 1) Study of literature relating to issues concerning the use of electrical energy in households, and planning for conducting research. 2) Formulate skills and expertise related to the issue of electricity use so that they are directed to the research objectives, and carry out a limited feasibility study of the study which includes electricity customers. 3) Develop the initial form of the product that will be produced through the initial design with a picture of the electrical circuit in accordance with Figures 5, 6, and 7. Check the readiness of supporting components, prepare guidelines and manuals, and then evaluate the feasibility of electrical components used in research which includes inductors, capacitors, autotrafo slides, and coils. Next to actualize the design that has been made. 4) Conducting initial field trials on a limited scale by involving subjects as many as 6-12 household electrical systems. In this step the collection can be done by interview, observation or questionnaire given to household electricity customers. The collected data is then analysed with descriptive comparative. 5) Make improvements to the initial product produced based on the results of the initial trial. This improvement is very likely to be done more than once, in accordance with the results shown in limited trials, so that new products are better and ready to be tested more widely. 6) The main trial to the number of electricity customers that involve more students in the technical implementation. Data collection is also carried out by means of interviews, observations or questionnaires given to household electricity customers. Furthermore, the data is analysed with percentage descriptions. 7) Make improvements / improvements to the results of the main trial, so that the product developed is already an operational model design that is ready to be validated.
Figure 5. Design of Voltage Plus Stabilizers

Figure 6. Design of Servo Motor Circuit Voltage Sources
4. Results

In the trial process, we use electric loads in the form of induction motors and pure resistor loads. By applying a passive filter to the electrical load installation this causes a decrease in load current and a decrease in measured electrical power. For smaller load currents, a smaller electric power savings also occur. The greater the load current, the greater the savings generated. Here are some examples of real loads carried out in this study using one inductor filter.

| NO | Arus Beban Tanpa Filter (Amper) | Arus Beban dengan Filter (Amper) | Daya Terukur tanpa Filter (Watt) | Daya Terukur dengan Filter (Watt) |
|----|--------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 1  | 0.28                           | 0.25                            | 12                              | 11                                |
| 2  | 0.56                           | 0.50                            | 30                              | 27                                |
| 3  | 0.84                           | 0.75                            | 60                              | 54                                |
| 4  | 1.12                           | 1.00                            | 101                             | 91                                |
| 5  | 1.37                           | 1.25                            | 149                             | 134                               |
| 6  | 1.70                           | 1.50                            | 225                             | 200                               |
| 7  | 1.97                           | 1.75                            | 295                             | 263                               |
| 8  | 2.25                           | 2.00                            | 380                             | 339                               |
Table 3. Several other examples are experimented according to the following table

| NO | Filter | Arus Beban (Amper) | Penghematan Daya (Watt) |
|----|--------|--------------------|-------------------------|
| 1  |        | 0.5                | 1                       |
|    |        | 1.0                | 5                       |
|    |        | 1.5                | 12                      |
|    |        | 2.0                | 20.8                    |
|    |        | 2.5                | 32                      |
|    |        | 3.0                | 46.2                    |
|    |        | 3.5                | 62                      |
| 2  | 12.5 uF | 0.5                | 2.9                     |
|    |        | 1.0                | 10.9                    |
|    |        | 1.5                | 24.2                    |
| 3  | 12.5 uF | 0.5                | 2.7                     |
|    |        | 1.0                | 10.7                    |
|    |        | 1.5                | 23.7                    |
| 4  | 12.5 uF | 0.5                | 2.6                     |
|    | 12.5 uF| 1.0                | 10                      |
|    |        | 1.5                | 22.1                    |

The two tables above illustrate that passive filters can reduce the absorption of power from the load operated by its users. The use of this filter circuit can save electricity usage up to 15% at a load current of 2 amperes. Thus electricity payment can be reduced by 15%. The greater the electrical load being operated, the greater the savings.

5. Conclusion
From this research there are two things that can be used as conclusions, namely 1) The use of passive filters in the installation of electrical loads can save power consumption, 2) The use of electricity loads is increasingly large, and the savings are also increasing. This research is only carried out on one phase electricity loads therefore it is recommended to other researchers to try on three phase loads.

6. References
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