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# Study of the Effect of the Use of Series Reactive Power Compensators on the Increase in Inductive Load Power Factor with Magnetic Energy Recovery Switches in Household Environments

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ABSTRACT

The use of inductive loads in modern household electrical installations is increasing, particularly in multi-story homes equipped with elevators, water pump drive motors, and generators. Such inductive loads lead to a decrease in power factor due to the dominance of reactive power, which negatively affects the efficiency and cost of electricity consumption. This study aims to improve the power factor in a three-story residential electrical system by implementing a reactive compensation method using a Magnetic Energy Recovery Switch (MERS) circuit. The system design and analysis are based on active power data obtained through the Autodesk Revit 2024 application, with load parameters sourced from the F-H05 elevator, Grundfos pump motor, and Weichai Power generator. Simulation was carried out using PSIM software to determine the optimal capacitor value and triggering angle for the IRF820 MOSFET. The simulation results show that the application of MERS significantly improves the power factor, making the system more efficient and cost-effective.

## 1. Introduction

Currently, the load on the electric power system in the household sector is generally inductive, which leads to a low power factor [1]. To overcome this, a device that is able to compensate for the inductive reactance of the load is needed [2]–[4]. Series reactive compensators are one solution, as they can supply and absorb reactive power through the setting of the ignition angle [5]. Its application can affect system parameters such as voltage stability and power factors, and help reduce power losses, improve power flow, and improve voltage profiles [6]. In general, electrical loads are divided into three types: resistive, inductive, and capacitive [7]–[9].

A three-story residential house project requires a large supply of electricity through a three-phase system, primarily to operate equipment such as elevators, generators, and water pumps, which are mostly inductive loads [10]. Inductive loads have a wire winding component in them, and increasing their use will increase the consumption of reactive power, which has an impact on the decrease in the quality of electrical power, especially the power factor [11]. The power factor (cos φ) is the ratio between the active power (Watts) and the visible power (VA), which decreases as the inductive load increases [12]. This factor is an indicator of the efficiency of power distribution in a system [13]. Therefore, accurate monitoring of power and power factors is very important because they both have a direct effect on the amount of electricity bills [14].

Referring to previous studies [15]–[20], this study aims to provide development solutions through the optimization and efficiency of the use of the MERS (Magnetic Energy Recovery Switch) program in household systems that use inductive loads. The goal is to increase the power factor in a system with a three-phase voltage source. The analyzed load parameters include pump motors, elevators, and generators, which were obtained through the results of modeling a three-storey house using the Revit 2024 application.

## 2. Methods

This study discusses the analysis of the use of series reactive compensators against the power factor at inductive loads by applying magnetic energy recovery switches (MERS) in the author's home design project. The research process is carried out through several structured stages. The series of procedures is described systematically through the flowchart shown in the following sections.

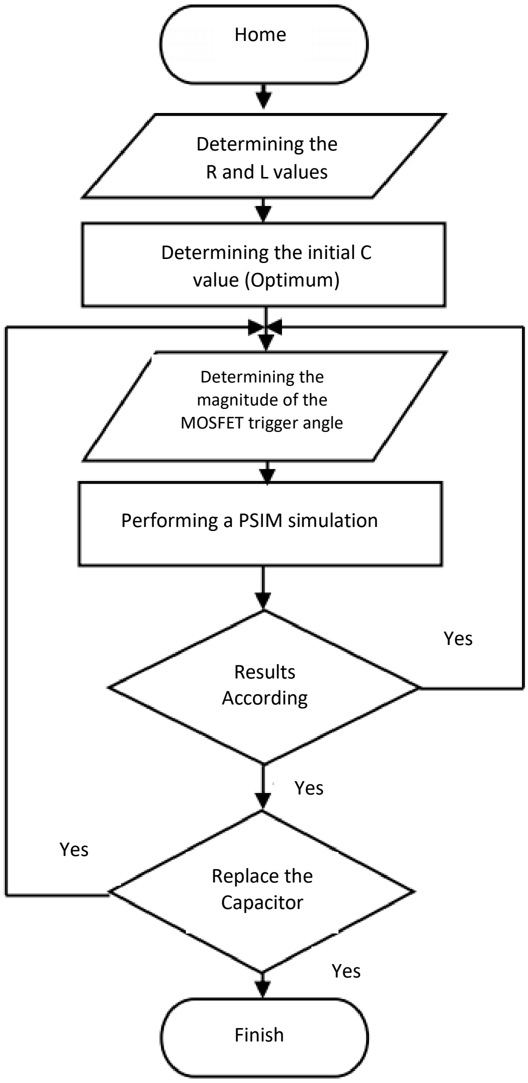


**Figure 1:** Flowchart of Research Design.

This study uses a quantitative approach, which is carried out by analyzing a sample of electrical installations in a house. The design results in Revit are then used to collect quantitative data and can test hypotheses regarding the increase in power factor. The quantitative method applied was an experiment, in which a sample of a three-storey house electrical circuit installation was made using the Revit 2024 application. From this, data were obtained that showed the influence of independent variables, such as active power, load amount, panel capacity, and operational duration, on dependent variables under controlled conditions. This controlled condition ensures that no other variables affect the dependent variables.

## 3. Results and Discussion

### *3.1. Results*

Currently, many households as electricity users have utilized various equipment that requires a three-phase electricity supply, such as water pump motors, elevators, and generators as backup resources in the event of a blackout. This condition is one of the important reasons to improve the quality of electrical energy utilization, one of which is through optimizing the power factor in the power grid. Electrical load analysis is a method that can be used to obtain active power data, and this can be done using the Autodesk Revit application. In this study, an electrical installation system for a three-storey house has been designed based on a team project from PT Solusi Utama Konsultan involving experts from the fields of architecture, civil engineering, and electrical engineering. Information about active power in the form of type properties is obtained after the process of connecting components (circuiting) is completed and all components have been connected to a power source, either through single-phase or three-phase panels. The 3D visualization of loads such as elevators, pump motors, and generators.

The F-H05 type elevator is equipped with a variety of features designed to provide comfort when used in residential environments. Details of the specifications can be seen in the following table 1.

**Table 1:** Elevator Specification.

| Brand | Fuji F-H05 |
|---|---|
| Type/Model | Home Elevator |
| Dimension | (0.8 m x 1 m x 1.2 m) |
| Country of Manufacture | Japan |
| Number of Poles | 3 PH |
| Voltage | 380V |
| Power | 1000W |
| Current | 2.6 A |

The Daeler Poma Grundfos motor functions as a pump drive with a flow capacity of up to 470 $m^3/h$. The full specifications of this device are presented in the following table 2.

**Table 2:** Specification of DAB Centrifugal Pump KDN.

| Brand | DAB Centrifugal Pump KDN |
|---|---|
| Type/Model | Water supply |
| Supply Voltage | 230-400V |
| Country of Manufacture | Japan |
| Number of Poles | 3 PH |
| Voltage | 380V |
| Power | 1000W |
| Current | 2.63A |

Generators with a capacity of 200 kW are used as a backup power source in the event of a blackout from the PLN network. The full specification details are presented in the following table.

**Table 3:** Specification of 200kW Generator.

| Brand | Alternator 200kW 250kVA Weichai Power Electric Generator |
|---|---|
| Type/Model | Self-Starting Diesel Generator |
| Output Type | AC 3 PH |
| Country of Manufacture | China |
| Number of Poles | 3 PH – 380V |
| Frequency | 60 Hz |
| Startup Mode | 24V DC Electric Start |
| Voltage | 250V |
| Power | 250W |
| Current | 1A |

# 4. Discussion

## *4.1. MERS Design*

This study uses a three-phase voltage source from PLN and involves loads in the form of generators, pump drive motors, and elevators as described in the previous data. In the MERS series, the N IRF820 MOSFET type is used which has a power of 80W, drain-source voltage (VDS) of 500V, maximum drain-source resistance (RDS) of 3 Ohms, and drain current (ID) of 4A at 25°C and 2.5A at 100°C.

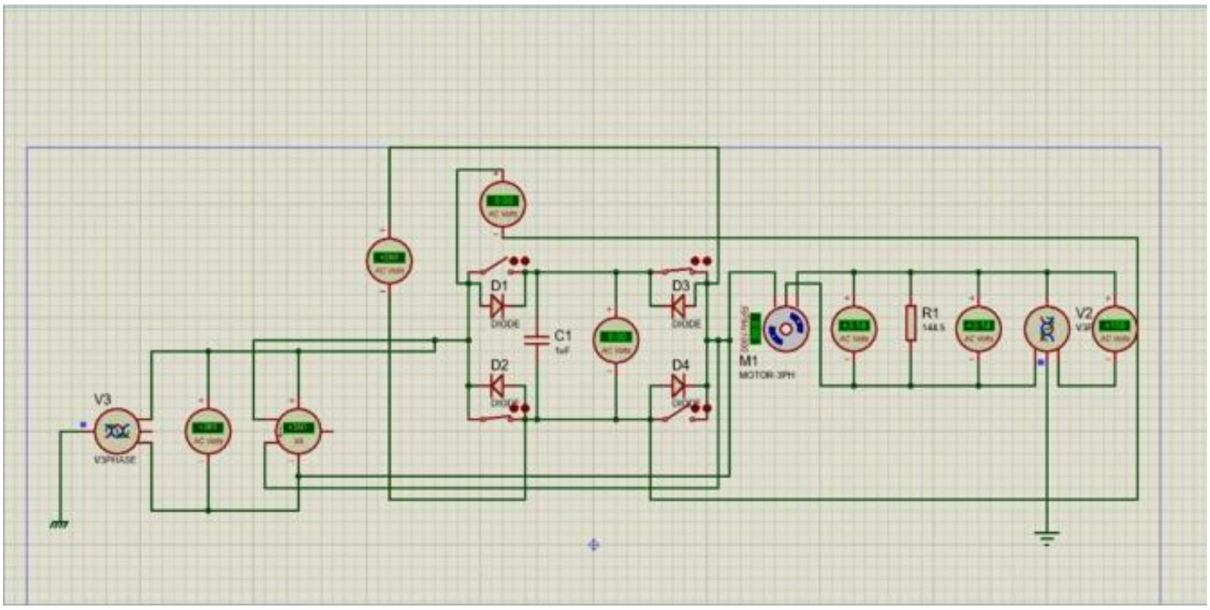


**Figure 2:** MERS Network on Proteus.

The values of the resistor (R) and the inductor (L) in the circuit are determined based on the parameters of the inductive load. Measurements are made against the source voltage (Vs), source current (Is), and power factor (cos φ) on the load object. The measurement results obtained are as follows:

- Source voltage (Vs) = 380 V
- Source current (Is) = 104.3 mA = 0.1043 A
- Power factor (cos φ) = 0.802, which is equivalent to phase angle φ = 36.68°

The total current sum of the elevator load, pump drive motor, and generator set is as follows:

- Elevator current = 2.63 A
- Pump motor current = 2.63 A
- Generator current = 1 A
- Total load current = 2.63 + 2.63 + 1 = 6.26 A
- R = 60.7 A

### *4.2. Load object measurement and simulation using PSIM11.1.3 software*

The initial measurement data was obtained by taking measurements directly on the research object without activating a series of MERS (Magnetic Energy Recovery Switch) switches. This data serves as a baseline in the simulation process carried out using Power Simulator software version 11.1.3.

**Table 4:** Elevator, Motor, and Generator Data Without Using MERS.

| Yes | Source | | | Initial Conditions | | | | | | THD | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vs | | F | P | Q | S | Pf | I | Vb | VTHD | ITHD |
| | Volts (ms) | Volt (peak) | Hz | Watt | VAR | VA | | A (ms) | Volts (ms) | % | % |
| 1 | 380 | 443,198 | 50 | 21,78 | 16,316 | 27,158 | 0,802 | 104,3 | 380 | 0 | 0 |

After identifying the parameters required for the measurement using the measuring tools present in the PSIM 11.1.3 simulation, the next step is to determine the MOSFET gate ignition angle. For Q2 and Q4 MOSFET gates, the start-up angle will be set from 0 to 180 degrees, while for Q1 and Q3 MOSFET gates, the start-up angle will be set between 180 to 360 degrees. Each change in the ignition angle is carried out in a 20° step at each stage of the simulation. The value of the capacitor used in the network is determined based on the calculation of the optimal capacitor which is 7 μF.

**Table 5:** Table of Initial Conditions + MERS.

| No | Sumber | | | Mers | | | | Kondisi Awal + Mers | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vs | | f | Sudut | Vc | Vmers | Mode | P | Q | S | Pf | I | Vb | THD (%) | |
| | Volt (rms) | Volt (peak) | Hz | (derajat) | Vmaks | Volt(rms) | | Watt | VAR | VA | | A (rms) | Volt (rms) | VTHD | ITHD |
| 1 | 380 | 443.198 | 50 | 10 | 386.797 | 368.244 | dc-offset | 1.02 | 4.144 | 4.267 | 0.239 | 0.0358 | 119.197 | 2.119 | 0.851 |
| 2 | 380 | 443.198 | 50 | 20 | 211.165 | 181.799 | dc-offset | 2.94 | 7.246 | 7.82 | 0.376 | 0.0564 | 138.656 | 1.005 | 0.404 |
| 3 | 380 | 443.198 | 50 | 40 | 243.891 | 185.551 | dc-offset | 12.501 | 14.422 | 19.086 | 0.655 | 0.0983 | 194.157 | 0.39 | 0.157 |
| 4 | 380 | 443.198 | 50 | 60 | 238.227 | 158.176 | dc-offset | 29.137 | 16.591 | 33.53 | 0.869 | 0.1365 | 245.638 | 0.143 | 0.057 |
| 5 | 380 | 443.198 | 50 | 75 | 207.425 | 116.736 | balance | 37.938 | 10.154 | 39.273 | 0.966 | 0.1451 | 270.662 | 0.018 | 0.007 |
| 6 | 380 | 443.198 | 50 | 100 | 156.744 | 120.986 | not-continous | 42.066 | 1.883 | 42.108 | 0.999 | 0.1501 | 280.534 | 0.073 | 0.033 |
| 7 | 380 | 443.198 | 50 | 120 | 107.792 | 98.193 | not-continous | 40.282 | 7.294 | 40.937 | 0.984 | 0.1478 | 276.128 | 0.109 | 0.053 |
| 8 | 380 | 443.198 | 50 | 140 | 52.159 | 45.35 | not-continous | 35.302 | 12.696 | 37.516 | 0.941 | 0.1415 | 265.128 | 0.118 | 0.059 |
| 9 | 380 | 443.198 | 50 | 160 | 95.544 | 49.807 | not-continous | 29.213 | 15.449 | 33.046 | 0.884 | 0.1329 | 248.655 | 0.099 | 0.049 |
| 10 | 380 | 443.198 | 50 | 180 | 45.112 | 47.818 | not-continous | 24.724 | 15.97 | 29.433 | 0.84 | 0.1258 | 233.967 | 0.055 | 0.026 |

Based on Table 5, the simulation results show that at the ignition angle between 0° to 75°, the system is in *dc-offset* mode, which indicates that the MERS reactance is greater compared to the capacitor reactance. The *balance* mode, where the MERS reactance is equivalent to the capacitor reactance, occurs exactly at a 75° ignition angle. Meanwhile, at an ignition angle above 75°, the MERS reactance becomes smaller than the capacitor reactance, resulting in a voltage waveform on the capacitor (Vc) that belongs to the *not-continuous* mode. The reactive power generated after MERS application is lower than the conditions before MERS was used. At a 100° ignition angle, the highest power factor value (cos ϕ) of 0.999 was obtained, with a reactive power of 1.883 VAR.

## 5. Conclusion

Electrical load analysis begins with building design using the Revit application. Once the design of the house is complete, electrical components are added to the model, followed by the circuiting process and connection to the 3-phase electrical panel. The simulation results show that the elevator load has a power of 1000 W with a current of 2.63 A, as well as the pump drive motor. Meanwhile, the load of the generator with the 2 kW type shows a power consumption of 250 W and a current of 1 A.

Furthermore, in the simulation of the circuit installation in the Proteus application, it was obtained that the reactive power generated after using MERS was smaller than before MERS was applied. This indicates an increase in system efficiency.

Advanced simulations using PSIM 11.1.3 show that when the reactance value of the capacitor is greater than the MERS reactance, the voltage waveform in the capacitor is in a not-continuous mode. When the capacitor reactance value is equivalent to the MERS reactance, the system is in balance mode. Whereas, when the capacitor reactance is smaller than the MERS reactance, the waves exhibit dc-offset characteristics. The capacitance value of the capacitor greatly affects the ignition angle of the MOSFET gate on the MERS circuit. Using a capacitor with a capacitance of 7 μF, the balance mode is achieved at a 75° ignition angle. At a 100° ignition angle, the system shows optimal performance with the highest power factor (cos ϕ) value of 0.999 and reactive power of 1.883 VAR.

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