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Simulation of AC-DC Buck Boost Converter Control Based on Fuzzy Logic

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ABSTRACT

Power quality is an important issue currently in the field of electrical equipment and electric power, so engineers do a lot of research on power quality. As technology develops, more and more electrical equipment is used, many electrical equipment use electronic power such as converters and others. Remembering previous research that has been carried out, namely, Simulation of AC-DC Buck Boost Converter Control with Proportional Integral Derivative (PID) using Matlab Simulink. For this reason, further research needs to be carried out with a different control system, namely fuzzy logic. By using fuzzy logic control, the simulation results show that fuzzy logic control is able to maintain the power factor value on the input side as well as the output voltage and output current values on the AC-DC buck boost converter. The rise time value shows a short and constant value based on each V reference. However, the overshoot value was not found, nor was the peak time, peak time was not found because there was no overshoot value in the output voltage and output current waveforms in the AC-DC buck boost converter simulation with a fuzzy logic controller using Matlab Simulink.

Keywords: Fuzzy Logic, Buck Boost,and Converter

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1. INTRODUCTION

The power quality of an electric power system or electrical equipment that is frequently used is a very important concern. Technological developments, especially in the field of electrical equipment, are very rapid, making engineers and researchers continue to carry out research and research. There are many electrical equipment that are often used in everyday life, such as cellphones, refrigerators, blenders, televisions, Uninterruptible Power Supply (UPS), power banks, chargers and others, all of which of course need to pay attention to the quality of the power produced.

RememberPrevious research that has been carried out is simulating an AC-DC buck boost converter with Proportional Integral Drivative (PID) control using Matlab Simulink. From the results of this research, it can be concluded that there are still overshoot, rise time and peak time values. The greater the reference voltage provided, the greater the rise time and peak time and the simulation results show that the PID control is able to maintain the power factor value on the input side, as well as the output voltage and current values on the AC-DC buck boost converter (Faisal et al., 2023) . So from the results of this research it is necessary to carry out further research with different controls, namely fuzzy logic control.

Currently there are many control systems being developed, especially buck boost converter control techniques. In the future, the control system in the electric power system will continue to be used because of its efficient use, besides that the control system has a fast response and high accuracy. With a control system, many parameters can be analyzed on the buck boost converter. Almost all electrical equipment has electronic power which functions to supply electrical power to the equipment. Many electrical equipment used in everyday life to supply electricity use the AC-DC working systembuck boostconverter.

AC-DC converters have a sequential working principle, namely,rectiviating(Rectifier), filtering(Smooth), and regulating(Arrangement).Functions and objectives of the stagesrectiviatingis the process of straightening voltagealternate current(AC) becomes Voltagedirect current(DC). Meanwhile, in stagesfiltering, usually uses a capacior whose function is to smooth the voltage. Then stageregulating,which aims to regulate the output voltage (Faisal et al., 2023).

There are many techniques that are often used in creating systemsregulatingconverters, including such asBuckconverter with voltage functionoutputsmaller than the voltageinput.Next there is a boost converter whose function is that the output voltage is greater than the input voltage or the opposite of the buck converter. Apart from that, there is also a buck boost converter technique with the output voltage function being greater or smaller than the input voltage. It is likely that rugulating techniques will continue to develop along with the increasingly rapid development of electronic technology, which is proven to be increasingly found in power electronics and electrical power systems.

Further research this time will be tested using AC to DCdiodebridge rectifier (diode bridge rectifier) and the regulator system used is a buck boost regulator with a resistive load. In principle, a buck boost converter regulator has a power MOSFET as a switching component which functions as a regulator of the output voltage in the circuit. In regulating the size of the output voltage, it will be regulated based on the PWM (Pulse Width Modulation) duty cycle (D) value)on the MOSFET switch. When the duty cycle value is greater than 0.5 then the output voltage will be greater than the input voltage, if the duty cycle is smaller than 0.5 then the output voltage will be smaller than the input voltage while the input voltage is the same as the output voltage when the duty cycle is the same with 0.5. In this test, the duty cycle value will be varied, which is determined based on the output voltage using a fuzzy logic control system.

This test aims to determine the power quality of an AC-DC buck boost converter with fuzzy logic control using Matlab Simulink. The use of fuzzy logic control in this trial is to analyze the output voltage on the AC-DC buck boost converter by paying attention to the overshoot, rise time and peak time based on the desired voltage (Vreference) or output voltage characteristics. on an AC-DC buck boost converter with Matlab Simulink software.

SoftwareMatlab has many tools and can be used in various fields of science, especially in the field of electrical power. In the Matlab software there are also libraries that are often used in running mathematical simulation models, signal processing and control systems. Matlab software also has Matlab Simulink, which is a programming that uses blocks, which can make it easier to simulate a designed system such as an electric power system and electronic power (Faisal et al., 2023).

2. RESEARCH METHODS

2.1. Power Quality

Power quality will remain a major issue in this decade as electricity users and utilities increase. Since electrical systems have been applied to consumers, power quality has probably become a significant problem. Power Quality is a concept that describes the good or bad quality of the electrical power supplied. Good power quality is very important to ensure electrical equipment operates optimally and avoids damage (Rashid, 2004).

In interpreting power quality, many different definitions are found, by Therefore, you need to know that when interpreting power quality you must look at standardization in interpreting it. For example, you can give an example The quality of electrical reliability used means that a static figure of 95% means it is said to be reliable quality. However, an industrial factory can interpret the quality of electrical power which is a characteristic of an electrical power supply can run the equipment in the industry to work properly. The characteristics in question can be very different for various criteria.

The value of the energy sent and distributed is known as power, by multiplying the magnitude of the voltage and electric current, where the amount of electric power is proportional to the product of the magnitude of the voltage and electric current. The electric power supply system can be controlled by the quality of the voltage, and cannot be controlled by electric current because the electric current is on the individual load side, so basically power quality is the quality of the voltage itself (Dugan et al., 1996).

In general, there are many types of problems in electrical power quality, some of which are, such as [5]:

1. Transition Symptoms (Transient), namely symptoms of changes in variables (voltage, current, etc.) that occur during the transition period from a soft operating state (steady state) to another state.
2. Symptoms of Short-Duration Voltage Changes (Short-Duration Variations), namely symptoms of changes in voltage values in a very short time, namely less than 1 (one) minute.
3. Symptoms of Long-Duration Voltage Changes (Long-Duration Variations), namely symptoms of changes in voltage values, over a long period of time, namely more than 1 (one) minute.

4. Voltage imbalance, namely a symptom of differences in the magnitude of the voltage in a three-phase system and its phase angles.
5. Wave Distortion, namely the symptom of deviation of a wave (voltage and current) from its ideal form in the form of a sinusoidal wave.
6. Voltage Fluctuations, namely symptoms of systematic changes in voltage magnitude.
7. Symptoms of Changes in Power Frequency are symptoms of deviations in the electric power frequency in an electric power system.

2.2. Converter

In the electrical power system, electric current consists of two types, namely alternating electric current or what is also calledAlternate Current(AC), the seconddirect electric current or what is often calledDirect Current(DC).The required electricity source may be different from the available electricity source, including the characteristics of the electricity source. A converter is a device that converts electrical power from one form to another form of electrical power. There are four classifications of converters that are often used, namely:

a. AC - DC converter (rectifier)
b. AC converter - AC (cylocconverter)
c. DC - DC converter (DC chopper)
d. DC - AC converter (inverter)

An AC-DC converter is simply a device for converting alternating current (AC) electrical power into direct current (DC). Direct current (DC) can be obtained from a battery or from a 220 Volt 50 Hz AC power source which is converted into direct current through a rectifier circuit. All AC-DC converters usually work in the following stages:

a. Rectification/Rectifier (rectifies AC voltage to DC).
b. Filtering/Filter (smooths DC voltage).
c. Regulating/Regulator (sets the output voltage according to specifications)

2.3. Rectifier(rectifier)

Usually rectifying AC current to DC is done using diodes. A rectifier refers to the process of converting alternating current (AC) to direct current (DC) using power diodes. After the rectifier diode is installed in a circuit that requires it, it will produce an output that approaches direct current (DC) or produce current and voltage waveforms that contain direct current (DC) with certain specifications. Based on the number of diodes used, there are two types of single-phase diode rectifiers, namely:

a. Half wave diode single phase rectifier
b. Full wave diode single phase rectifier
   The full wave rectifier circuit can be obtained in two ways. The first method requires a central tapping transformer (Centre Tap-CT). Another way to get full wave output is to use four diodes called a bridge rectifier.

2.3.1. Single phase full wave rectifier with transformer

A full wave rectifier circuit with a center tapped transformer is shown in Figure 1. Each part of the transformer with its associated diode functions as a half-wave rectifier. The output of a full wave rectifier is shown in Figure 2. Because there is no DC current flowing through the transformer, there is no DC saturation problem in the transformer core [4]. The average output voltage (Vout) is shown in Equation (2.1).

$$V_{dc} = \frac{2}{T}\int_0^{T/\pi} V_m \sin\omega t dt = \frac{2V_m}{\pi} = 0,6366\, V_m \quad (1)$$

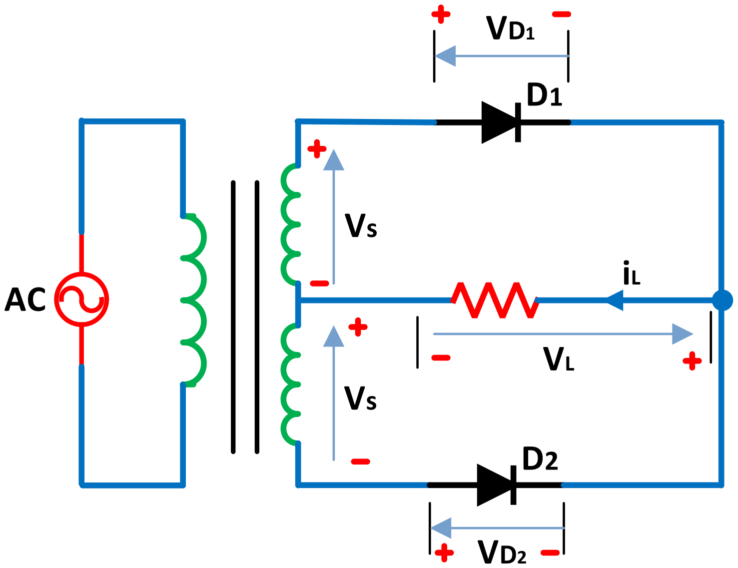

Figure 1. Full wave rectifier with center tapped transformer

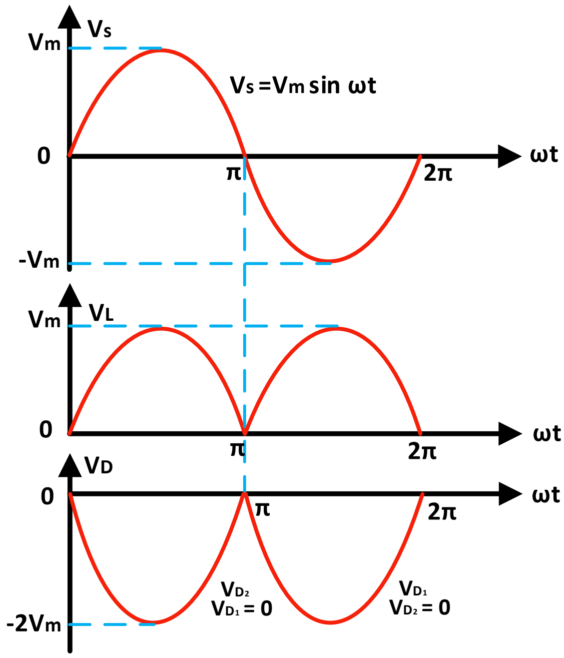

Figure 2. Full wave rectifier output with transformer central lead

2.3.2. Transformerless single phase full wave rectifier.

Apart from using a central tapping transformer, the full wave rectifier circuit can also use four diodes as shown in Figure 3. As long as the input voltage (Vin) experiences a positive half cycle, power is supplied to the load through diodes D1 and D2. During the negative cycle, diodes D3 and D4 conduct. The waveform for the output voltage (Vout) is shown in Figure 4. The peak voltage of the diode is just Vm. This circuit is known as a bridge rectifier (Dugan et al., 1996).

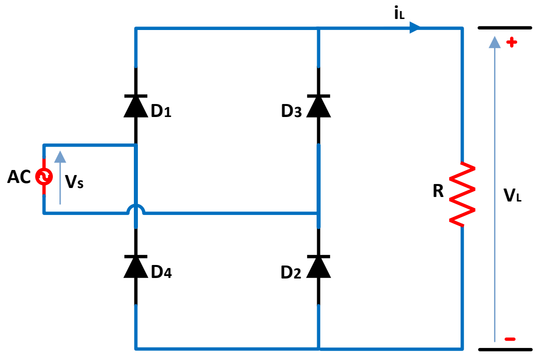

Figure 3. Transformerless full wave rectifier

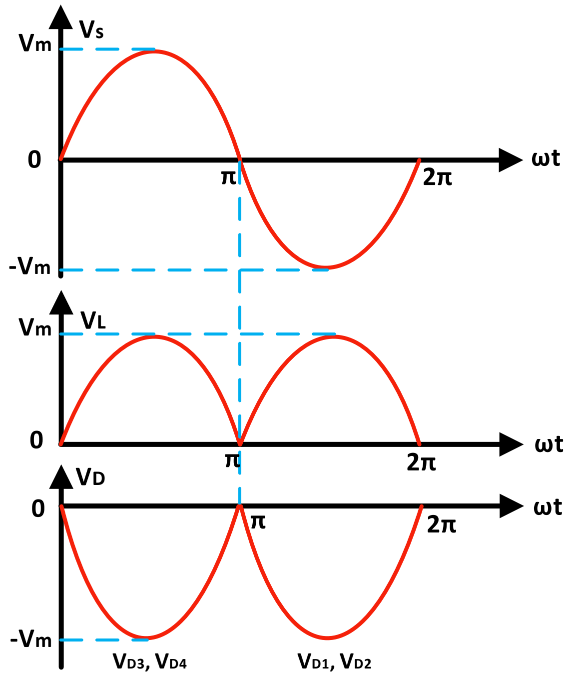

Figure 4. Full wave rectifier diode output without transformer

2.4. Filtering/Filter

The purpose of rectification is to obtain direct current. In a rectifier, pure direct current is not obtained but rather direct current which changes periodically, so this direct current still contains an alternating current signal. To eliminate the remaining alternating waves, an electrolytic condenser is often used as a leveling filter or what is often called a filter which functions to obtain an even unidirectional output voltage (Vout) from therectifier circuit). This voltage variation is called voltage ripple. The voltage ripple in a full wave rectifier is smaller than the voltage ripple in a half wave rectifier. To further reduce this voltage ripple, a filter is used which is responsible for smoothing unidirectional components and preventing alternating components. The rectifier circuit equipped with a C filter (capacitor) is shown in Figure 5. So that the AC wave rectification voltage is more even and becomes a DC voltage, a C filter (capacitor) is installed at the output of the rectifier circuit.

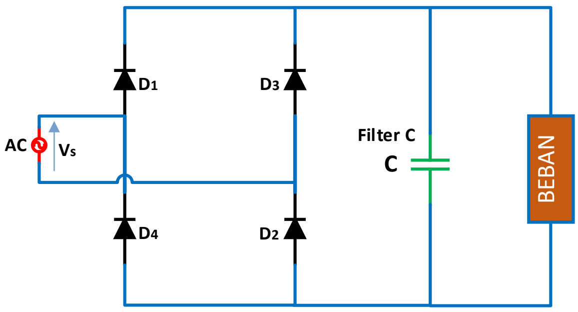

Figure 5. The rectifier circuit is equipped with a C filter

After installing filter C, the output of this full wave rectifier circuit will be a DC (direct current) voltage which can be calculated mathematically with Equation (2.2).

$$V_{dc} = \frac{2V_{m}}{\pi} \quad (1)$$

By adding a capacitor parallel to the load in the full wave rectifier circuit, the voltage ripple will be greatly suppressed. As we know, capacitors can store energy. When the source voltage increases, the capacitor will charge until it reaches the maximum voltage. When the source voltage decreases, the capacitor will release the energy it has stored through the load (because at this time the diode is not conducting). In this way, the load will still receive energy flow even though the diode is not conducting. Furthermore, if the diode conducts again, the capacitor will be charged and this stored energy will be released again when the diode is not conducting, and so on. Figure 2.6 is the full waveform of the DC output voltage which contains ripples and shows filter C when charging (charger) and when discharging (discharger).

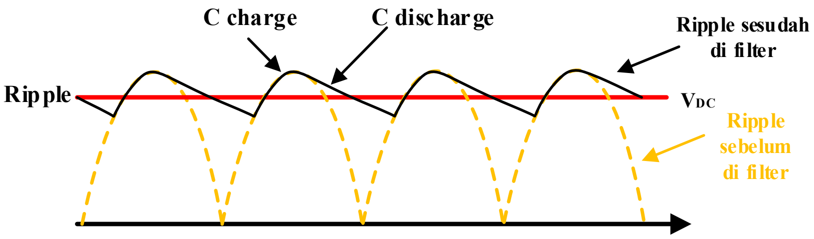

Figure 6. DC output voltage ripple

2.5. Fuzzy Logic

SFuzzy can be interpreted as vague, in other words, fuzzy logic is vague logic. Where in fuzzy logic a value can be 'true' and 'false' simultaneously. The level of 'true' or 'false' values in fuzzy logic depends on the membership weight it has. Fuzzy Logic has a membership degree ranging from 0 to 1, in contrast to digital logic which only has two memberships of 0 or 1 at one time.

Fuzzy logicoften used to express a value that is translated into simple linguistic language in determining control actions. To develop fuzzy rules, a good understanding of process and output control is required. Fuzzy logic does not require complicated mathematical modeling, all that is needed is input and output mapping.

Figure 7 is a fuzzy logic controller (FLC) as an alternative to a modern control system that is easy because there is no need to look for a mathematical model of a system, but it is still effective because it has a stable system response. Fuzzy logic functions to represent something that is uncertain and imprecise in the system, while fuzzy control makes it possible to make decisions even though the input or output of the system is uncertain and cannot be predicted.

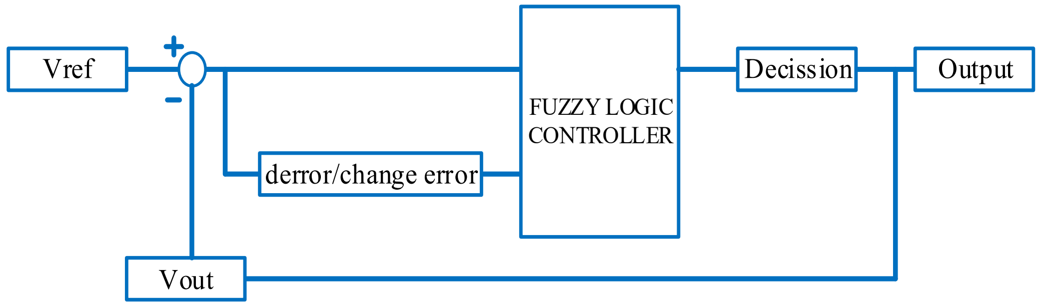

Figure 7. Fuzzy logic diagram for controller modeling on buck boostconverter

There are several reasons for using fuzzy logic, including [8], [9], [10]:

a. The concept of fuzzy logic is easy to understand.
b. Fuzzy logicvery flexible.
c. Fuzzy logichave tolerance for inaccurate data.
d. Fuzzy logicable to model complex non-linear functions.
e. Fuzzy logiccan work together with conventional control techniques.
f. Fuzzy logiccan build and apply the experiences of experts directly without having to go through a training process

3. METHOD

In this research, a research approach was carried out using Matlab Simulink software, for the experimental model design method this time to see the results of Fuzzy Logic control on the buck boost converter system. The converter created in the Matlab Simulink simulation is an AC to DC converter whose function is to change AC voltage to DC voltage. Then a capacitor is added to the simulation circuit with the function of smoothing the DC voltage before the voltage enters the buck boost converter regulator section. The overall circuit configuration that will be simulated in Matlab Simulink can be seen in Figure 8.

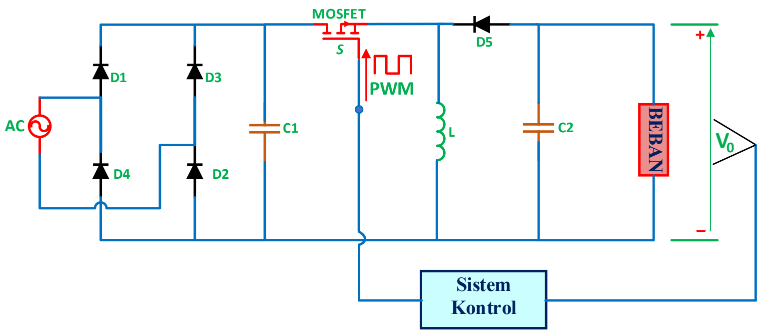

Figure 8. Buck boost AC-DC converter circuit diagram configuration with control system

The circuit consists of four diodes whose function is to rectify AC voltage into DC voltage and this is what is called an AC to DC converter with a one phase full wave rectifier without a transformer (uncontrolled rectifier). After the diode is installed, a capacitor is installed which functions to even out or smooth the DC voltage coming out of the diode. Next, go to the buck boost converter regulator section which consists of a MOSFET as a switch, inductor (L), capacitor (C) and diode (D) components, with the function of adjusting the voltage as desired. And the load used is a resistive load (R).

For the simulation to run in Matlab Simulink, a series of experiments and component parameters must be adjusted to the needs of the circuit to be tested. In Matlab Simulink, the overall series of buck boost converter modeling simulations with fuzzy logic control can be seen in Figure 3.2. With fuzzy logic controlconsists of two inputs, namely: error e(k) and derrorΔe(k), error e(k) is the difference from Vreference (Vref) to the output voltage (Vout), while errorΔe(k) is the difference between the current error and the previous error, shown in Equations below. respectively.

e(k) = Vref - Vo(k)

Δe(k) = e(k) - e(k-1)

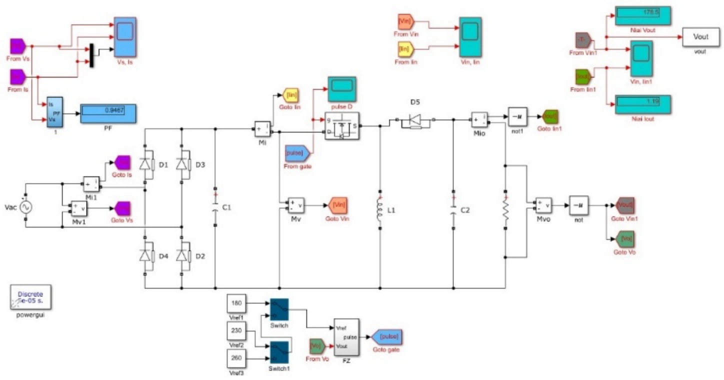

Figure 9. Modeling of an AC-DC buck boost converter circuit with fuzzy logic control

4. RESULT

4.1. Simulation Results Of 230 V Reference With Fuzzy Logic Control.

The test results in this chapter will discuss the simulation of an AC-DC buck boost converter with a fuzzy logic controller using Matlab Simulink software. Simulation tests using Matlab Simulink software with fuzzy logic control on the AC-DC buck boost converter were carried out three simulations based on the Vreference (desired voltage) with voltage variations of 180 V, 230 V and 260 V. With the Vreference that will be simulated you can pay attention to the power quality of each -each of the tests.

By simulating the AC-DC buck boost converter circuit with fuzzy logic control based on Vref 180 V in Matlab Simulink software the voltage waveform is shown in figure 10. To obtain accurate data values, this is done by using a data cursor and inserting magnification of the output voltage and current waves in the Matlab Simulink software.

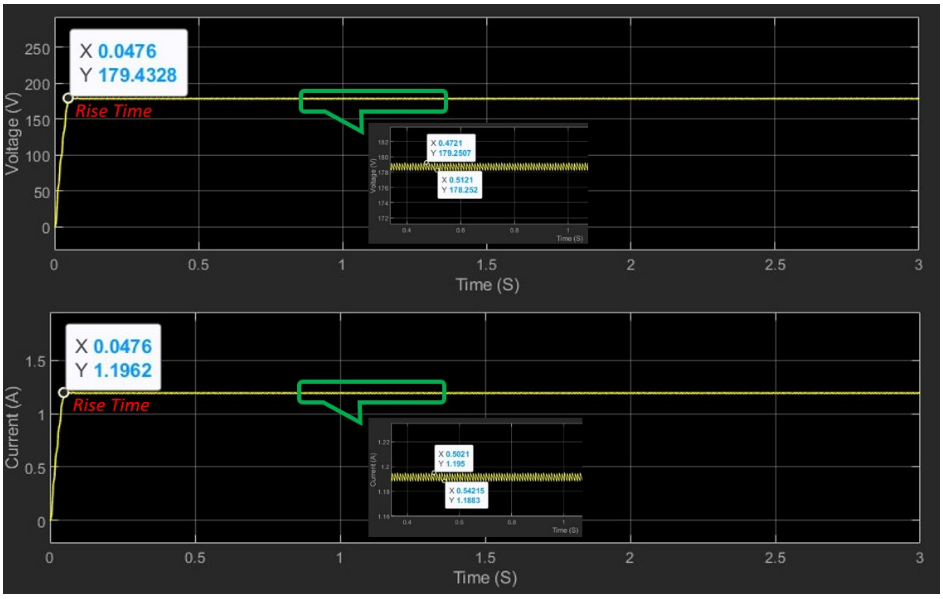

Figure 10. Output voltage and current waveform based on Vref 180 V

From Figure 10, it is known that the x-axis is time (s) and the y-axis is the output voltage (Vout) and output current (Iout). Based on the 180 V reference using fuzzy logic control from the cursor data and insert magnification of the output voltage and output current waves, the output voltage (Vout) value is 178.25-179.25 V and the output current (Iout) value is 1.18-1 .19 A, then the rise time value obtained is 0.047 ms. However, there is no overshoot value in the output voltage and current waveforms and it does not show any peak time because there is no overshoot value in the AC-DC buck boost converter simulation results based on Vref 180 V.

For the power factor (PF) value on the input side of the AC-DC buck boost converter with fuzzy logic control obtained from the power factor value calculation display in the simulation circuit based on 180 Volt Vreff, the power factor value is 0.9467, which can be seen in the figure. 11

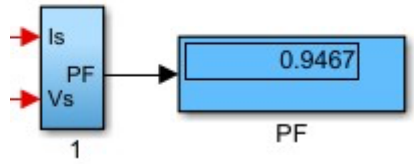

Figure 11. Power factor display value on the input side with Vref 180 V

Simulations based on Vref 230 V were carried out in the same way as Vref 180 V. The simulation results of AC-DC buck boost converters with fuzzy logic control based on Vref 230 V obtained output voltage (Vout) values of 228.37-229.82 V and current values. The output (Iout) was obtained at 1.52-1.53 A, then the rise time value was obtained at 0.070 ms. However, there is no overshoot value in the output voltage and current waveforms and does not show any peak time because there is no overshoot value in the AC-DC buck boost converter simulation results based on Vref 230 V. The output voltage and output current waveforms are shown in Figure 12.

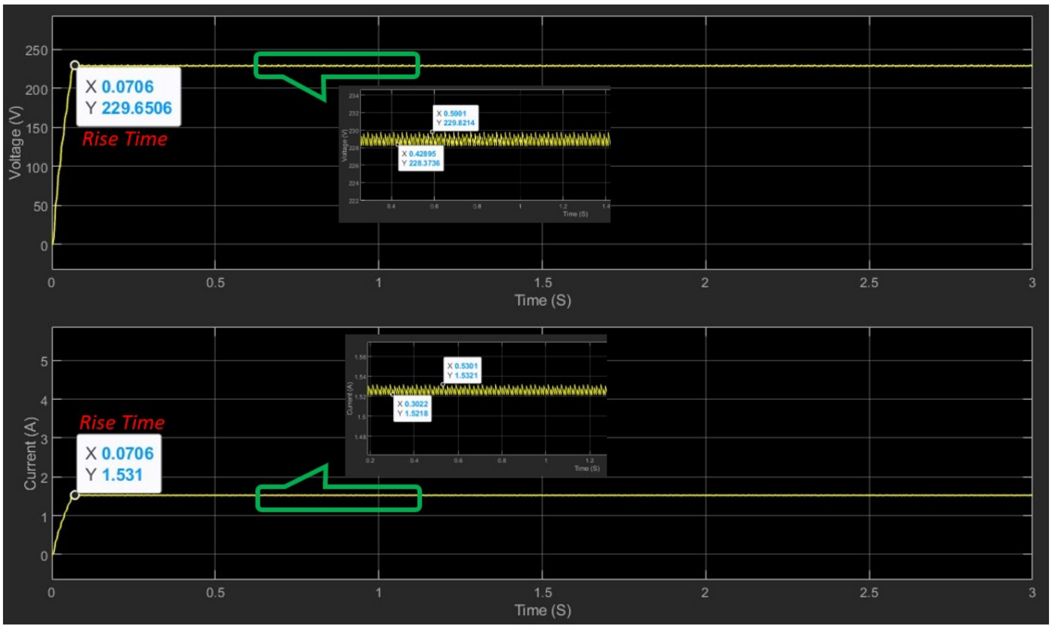

Figure 12. Output voltage and current waveform based on Vref 230 V

Meanwhile, the power factor (PF) value on the input side of the AC-DC buck boost converter with fuzzy logic control is obtained from the power factor value calculation display in the simulation circuit with Vref 230 Volts, a power factor value of 0.9479 is obtained, which can be seen in figure 13.

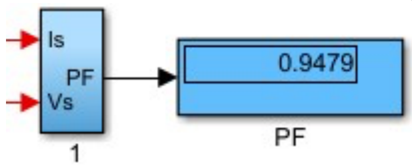

Figure 13. Power factor display value on the input side with Vref 230 V

4.2. Simulation results of 260 V reference with fuzzy logic control

Next, the same as with Vreference 180 V and Vreference 230 V, based on Vreference 260 V, the simulation results of the AC-DC buck boost converter obtained an output voltage value of 258.25 - 259.94 V and an output current value of 1.72 -1.73 A , Meanwhile the rise time value was obtained at 0.077 ms. For overshoot no value was found and likewise for peak time, the peak time value was not found because no overshoot value was found for the output voltage and current waveforms in the simulation results. The output voltage and output current waveforms are shown in Figure 4.5.

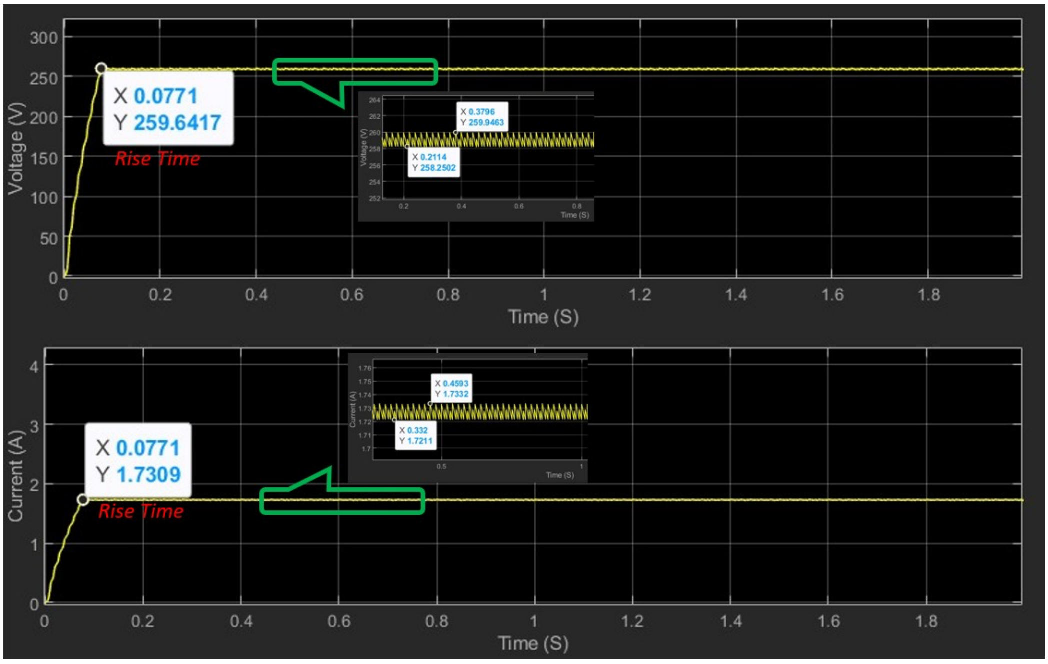

Figure 14. Output voltage and current waveform based on Vref 260 V

Meanwhile, the power factor (PF) value on the input side of the AC-DC buck boost converter obtained from the power factor value calculation display in the simulation circuit with Vref 260 Volts obtained a power factor value of 0.9484, as shown in Figure 4.6.

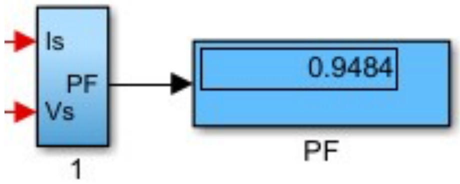

Figure 15. Power factor display value on the input side with Vref 260 V

4.3. Discussion

To clarify the data obtained based on the simulation results of an AC-DC buck boost converter with fuzzy logic control based on varying Vref, namely 180 Volts, 230 Volts and 260 Volts, it can be seen in tables 1 and 2 below:

Table 1. Values of output voltage, output current and power factor from simulation

No	Vreference	Vout	Iout	Power Factor
1	180 V	178.25 - 179.25 V	1.18 - 1.19 A	0.9467
2	230 V	228.37 - 229.82 V	1.52 -1.53 A	0.9479
3	260 V	258.25 - 259.94 V	1.72 - 1.73 A	0.9484

Table 2. Overshoot value, rise time and peak time of output voltage and current *simulation output with fuzzy logic control*

No	Characteristics	Vreference 180 V	Vreference 230 V	Vreference 260 V
1	*Rise Time*	0.047 ms	0.070 ms	0.077 ms
2	*Peak Times*	-	-	-
3	*Max Overshoot*Vout	-	-	-
4	*Min Overshoot*Vout	-	-	-
5	*Max Overshoot*Iout	-	-	-
6	*Min Overshoot*Iout	-	-	-

By paying attention to table 1 and table 2 from the simulation results of an AC-DC buck boost converter using fuzzy logic control, it can be concluded that the system can maintain the power factor value on the input side as well as the output voltage and current. The fuzzy logic control is able to maintain the voltage and current values. For value*rise time*with control*fuzzy logic*also maintained constantly based on eachVreference (desired voltage). Then the simulation results do not show any overshoot values in the output voltage and current waveforms, as well as peak time, there is no peak time because it does not show an overshoot value.

4.4. Program Suitability to Learning Outcomes

From the tests carried out in the form of a simulation of an AC-DC buck boost converter with control*fuzzy logic*The suitability of the program to learning outcomes can be adjusted to courses in power electronics, control systems and electric power control systems. In power electronics it is related to the material of converters and regulators and in control systems it is related to fuzzy logic control, proportional integral derivative (PID) and other controllers, while with electric power control systems it is related to the basic concepts of electric power control systems and types of control systems electric power.

5. CONCLUSION

From the simulation results that have been carried out and the test data obtained, it can be concluded:

1. The simulation results show that the fuzzy logic control is able to maintain the power factor value on the input side, as well as the output voltage and output current values on the AC-DC buck boost converter.
2. AC-DC buck boost converter simulation with fuzzy logic control. The rise time value shows a constant and short value based on each V reference. Meanwhile, the overshoot value was not found and neither was the peak time. The peak time was not found because there was no overshoot value in the output voltage and current waveforms.

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