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DRIVER FOR LED LAMP WITH BUCK CONVERTER CONTROLLED BY PID

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***Abstract*— As technology develops, innovation is increasingly getting significant developments, including in the area of lighting. The development of lamps for street lighting provides innovations, one of which is LED lamps. The buck converter LED Driver is an option due to its high efficiency, low cost, and small form. The problem is that the Buck Converter has a form of DC voltage that has a high ripple. The Buck Converter has an transient output voltage that appears at start up with a high overshoot. The varied source of AC is one of the problems in converter development. There is a potential for improvement in ripple and overshoot with the PWM control technique. PID is the most widely used choice considering that PID can easily adjust the Buck Converter output accuracy according to parameters. PID has a Mean Absolute Error (MAE) value of 0.8726, resulting in a setpoint difference of 4.8475% or a difference of 0.8726V.**

***Keywords*— PID, PI Controller, Buck Converter**

I. INTRODUCTION

The more technology develops, the more frequent innovations are getting significant developments, no exception to the field of lighting. The development of lamps for street lighting provides innovations, one of which is LED lamps. Light Emitting Diode (LED) lamps are considered an energy-efficient, environmentally friendly, and suitable light source to replace conventional lamps [1]. The LED Driver is essential considering that the Driver can determine the efficiency of an LED lamp. Many types of converters can be used in controlling LED lights, including Buck Converter, Buck-Boost Converter, Switch Mode Power Supply, etc. Buck Converter is an option due to its high efficiency, low cost, and small form [2].

Buck Converter is a DC-DC Converter that converts a larger DC voltage into a smaller DC voltage [3]. The problem is that the Buck Converter has a DC voltage form that has a high ripple [4]. The Buck Converter has an output transient voltage that appears at startup that has a high overshoot. This causes the LED Driver to decrease its lifespan and can reduce the effectiveness of the LED itself.

Also, the varied source of AC is one of the problems in converter development. Even though it has been changed to a DC source, these variations in the AC source can cause the input voltage to have variations that can change the Buck Converter's output.

There is a potential for improvement in ripple and overshoot with the PWM control technique. PWM control techniques can be done in various ways, such as PID, Fuzzy Logic Control, Adaptive Control, etc. [2]. PID is the most widely used choice considering that PID can easily adjust the Buck Converter output accuracy according to parameters [3]. To remove disturbance, it is recommended to use PI or PID controller. Transfer function with standard PI or PID controller and integrating plant has stable zero in numerator, which cause overshoot in step response y(t) [5]. Because of the simplicity in tuning, the PI controller are until now are mostly useful controller in industries. The PI controller is carried out from the input and feedback signal[6]. PID Controller depend on the extra error from control signal, same with reduce the impact of parameters change [7].

In this research, we will adjust the DC source input with various changes in the AC source. This study uses PID as a DC input control method to not change drastically and damage the LED load so that a constant LED driver is obtained.

II. SYSTEM DESCRIPTION

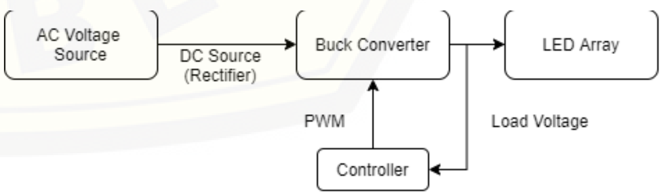

Figure 1 Block diagram of research

In this study, the AC voltage input source was used as the buck converter's voltage source. Then the AC voltage is converted into DC voltage using a rectifier. This is intended as an input that will be converted by the buck converter and the voltage that will turn on the LED array. For control, the buck converter is used as feedback from the buck converter output where the system is a closed-loop. The control system's output is PWM, which can adjust the size of the voltage to match the setpoint. It is intended that the buck converter output remains stable as the set value.

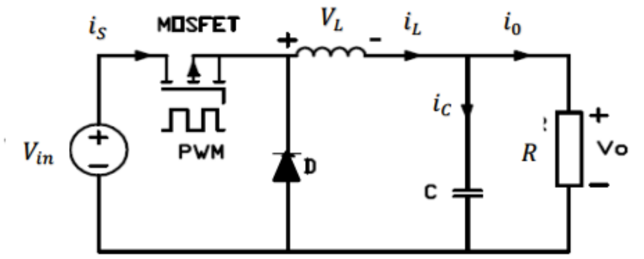

Figure 2 Buck Converter circuit with PWM controller

Buck Converter is a DC-DC Converter that converts a larger DC voltage into a smaller DC voltage. The buck converter has two conditions: when the duty cycle is on and when the duty cycle is off. This duty cycle regulates the switching of the buck converter. This switching will determine the current in the inductor and the output voltage.

The buck converter consists of components consisting of DC input, MOSFET, inductor, diode, capacitor, and control circuits and loads. The duty cycle described above will later measure the MOSFET used as a current counter to achieve the desired output. This MOSFET is controlled by a control circuit that will control the MOSFET to know when the MOSFET will open and close. The inductor in the buck converter circuit is used as energy storage in the form of the current so that when the MOSFET requires current when the MOSFET is open, the energy will be released. Diodes are used to drain the current generated by the inductor when the MOSFET is open.

The components used in the buck converter circuit are :

L = 200 µH
C = 220 µF
F = 25 kHz

In spite of so many advantages such as the ability to be employed in most process control systems, uncomplicated and straightforward in use and simple implementation, sometimes the other controllers can be more useful than PID controllers[8]. So in this research using the PI Controller to adjust the buck converter input to match the desired output. The PI controller has a tracking setpoint compared to the PID controller.

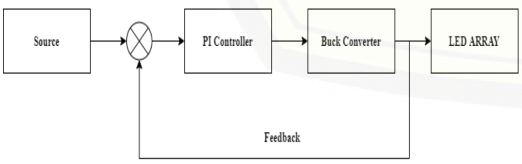

Figure 3 Block Diagram PI Controller

PI controller has an advantage over the PID controller. It provides PI in the inner loop, allowing the open loop unstable process to open loop stable process and, hence, can control integrating stable, unstable, and resonant processes [9]. But on the other side, PID controllers are reliable and straightforward. They are widely used in process industries, but their disadvantage is that they can be used only for non integrating process and not for integrating, unstable and resosnant processes as they do not provide good results. So in this research, we use PI Controller.

PID Controller is a controller that improves a system's accuracy with the characteristics of the feedback on a system [10]. The PID controller reduces the error value or the difference in output from the process against the input or setpoint that has been determined and entered into the system. PID Controller consists of three main components, namely proportional, integral and derivative. This PID component can be used individually or together depending on the desired system response.

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t)$$

From the above equation, it can be explained that the output value u(t) is the sum of proportional gain (Kp), integral gain (Ki), and derivative gain (Kd), each of which is affected by error (e) in the time interval (t) specific.

Proportional control (Kp) is a controller with the same output / proportional to the error signal size. This error value is the difference between the setpoint value and the actual value. The change in input causes the system to issue an output signal equal to its multiplier constant. The following equation can formulate the proportional control equation:

$$u(t) = K_p e(t)$$

Where :

K_p = Gain proportional

e = Error

u = The output value is relative to time (t)

Integral Control (Ki) is a controller that has the function of reducing the steady-state error value to close to 0 without eliminating the steady-state error. If a system does not have an integrator (1 / s), then proportional control does not guarantee that the system output will match the setpoint, so it must use integral control. The following equation can formulate the integral control equation:

$$u(t) = K_i \int_0^t e(t) dt$$

Where :

K_i = Gain integral

e = Error

u = The output value is relative to time (t)

Derivative control (Kd) has the same output magnitude as the general differential operation. Derivative control uses the rate of change of the error signal as a control parameter. So that derivative control cannot be used independently. If the error signal has no change, then the derivative control output is the same as before. The following equation can formulate the derivative control equation:

$$u(t) = K_d \frac{d}{dt} e(t)$$

Where :

K_d = Gain derivatives

e = Error

u = The output value is relative to time (t)

The PID Controller used in this study is a PI Controller type with the following specifications:

P=100
I= 0.0001

III. METHOD

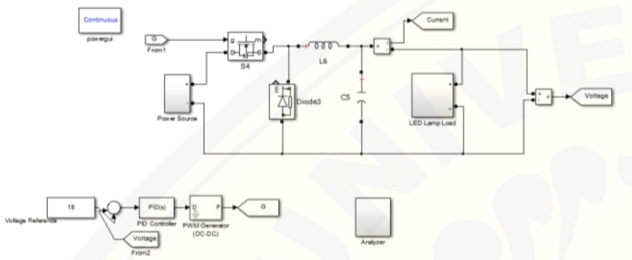

Figure 4 Dc-Dc Buck Converter Simulink Model

In this research method, the research uses MatLab Simulink to process data and simulate circuits. The circuit consists of a Source, Buck Converter, PI Controller, and Load. The AC source is made variable, and later the controller will stabilize the input so that the output matches the setpoint. The system is made a closed-loop so that the output becomes a reference voltage, the voltage that is not suitable will be informed to the controller, and the controller will adjust the output voltage later.

For testing, the Mean Absolute Error parameter is needed to determine the difference between the voltage setpoint used, namely 20VDC with the LED Driver's output. Mean Absolute Error (MAE) is a parameter used to calculate the difference between the average setpoint and the response value obtained. The smaller the parameter value, the better the system stability level. The following is the equation of the MAE:

$$MAE = \int_0^\infty \frac{1}{n} \sum_{i=1}^{n} |fi - yi|$$

In this research, using a PID Controller to adjust the buck converter input to match the desired output

The purpose of this test is to determine the ability of the Driver that has been designed to face various problems with the following conditions :

1. When the source conditions are unstable and not even following existing standards
2. When the LED lights are added, the load is added by installing multiple LED array lights within a certain period.

Therefore, the test is carried out with the following model :

1. System testing is done by increasing and decreasing the source voltage. This is adjusted to the conditions that might occur when the LED lights are attached to the user. The constant voltage increase and decrease that is generally used is 220 VAC and then reduced to 150 VAC, 100 VAC, and then returned to 220 VAC.
2. The load (LED Lamp) connects with 3 LED array lights and pairing them to the LED Driver's output with different periods. Each LED array has a power of 16.2 Watt but will be iterated four times. The first is 16.2W (1 Array), the second is 32.4W (2 Array), the third is 48.6W (3 Array), and the last is 16.2W (1 Array).

IV. RESULT AND DISCUSSION

To demonstrate DC-DC Buck Converter's performance, many simulations can be done using MatLab simulations and using the buck converter system modeling method, as shown in Figure 3. The input voltages that change are 220 VAC, 150 VAC, and 100 VAC. The switching frequency is 25kHz, and the load varies, which are 16.2W, 32.4W, and 48.6W.

The simulation shows that the output load voltage of the LED remains constant at 20 VDC. With the variation in the changing AC voltage source, namely 220VAC, 150VAC, 100VAC, then back to 220 VAC, the result is that the voltage at a constant LED load is 20 VDC in Figure 5. Figure 6 shows that the varying load variations make the current vary according to the existing load, but still, the voltage is the same at 20VDC.

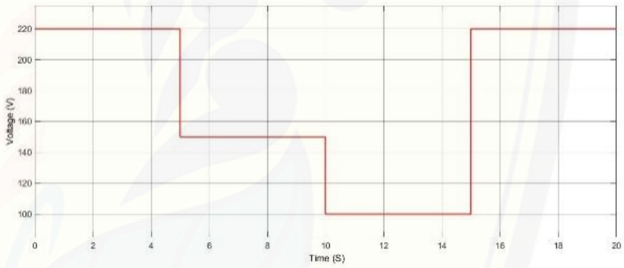

Figure 5 DC Voltage Source Variation

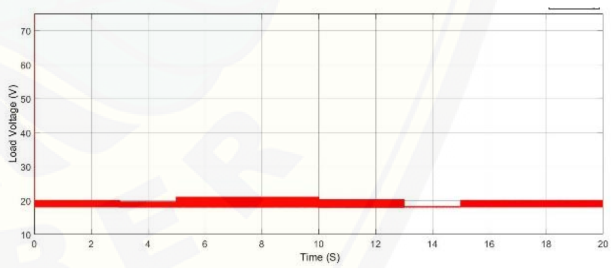

Figure 6 Variation of Load Voltage (LED)

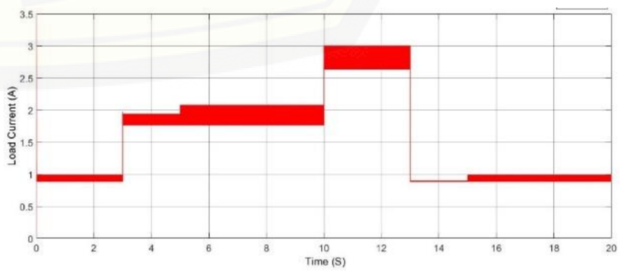

Figure 7 Variation of Load Current (LED)

Based on the MAE performance analysis results from the test results, it was found that the test was 0.8726 or had an average error and setpoint value of 4.8475%. Based on this, the average oscillation occurred with a set point of 4.8475% or a difference of 0.8726V. Overshoot does not occur at changes in voltage or increases in load. So it can be said that the system is very much following what is expected.

V. CONCLUSION

In this study, several conclusions were obtained: First analysis of varying VAC voltage produces a load voltage that is fixed at the setpoint, which is 20VDC. The second variable, LED load analysis, has a constant load voltage, but the current changes according to the load amount. Third, mean Absolute Error shows a value of 0.8726, resulting in a setpoint difference of 4.8475% or a difference of 0.8726V.

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