Comparative Analysis of Buck-Boost Converter with Sepic Converter for Optimization of Wind Power Plant Output Voltage

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Abstract. Energy is the main necessity for carrying out activities in various sectors. The fulfillment of energy is still dependent on fossil energy, which causes various negative impacts. Indonesia's location on the equator makes Indonesia an area of air movement. Some areas in Indonesia have considerable potential with an average wind speed of 4-5 m/s, and the potential energy generated reaches 60,647 MW. PLTB (Wind Power Plant) is one of the electrical energy generators with wind resources. However, the erratic wind speed affects the output voltage of the wind farm. Therefore, the use of new renewable energy plants still requires technology so that the resulting output voltage can be optimized. This research will analyze the comparison of the output voltage of the DC-DC buck-boost converter with the sepic converter on the wind farm. With an input voltage of 12VDC, the Buck-Boost converter output voltage results are higher than the Sepic converter. So buck-boost performance is better than the sepic converter. PWM settings also affect the output voltage results; the higher the percentage, the greater the voltage produced.

Keywords: component; buck-boost, converter, wind power plant.

1 Introduction

Energy is the main requirement for carrying out activities in various sectors. Energy fulfillment currently still depends on the use of fossil energy which causes various negative impacts. Weather conditions that are increasingly difficult to predict are one of the impacts that can currently be felt [1]. The demand to meet energy needs, especially cheap and affordable energy to obtain, is the reason for continuing to rely on conventional energy. It is projected that by 2050, Indonesia will still use conventional energy by 39% of the total national energy needs [2]. This certainly threatens energy availability, where the increasing demand is inversely proportional to national energy reserves.

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Indonesia's location on the equator makes Indonesia an area of air movement. Some areas in Indonesia have considerable potential with average wind speeds reaching 4-5 m/s, and the potential energy generated reaches 60,647 MW [3]. This abundant amount can be used as an alternative to substitute conventional energy to new renewable energy. This is also in line with the increase in the electrification ratio target to 100% by 2025, the electricity demand is projected to increase more than 7 times to 1,611 TWh by 2050 [4]. Currently, various types of power plants with renewable energy sources are being developed. Wind Power Plant (PLTB) is one of the electrical energy plants with wind resources. However, the uncertain wind speed affects the output voltage of the wind farm.

Therefore, the use of new renewable energy plants still requires technology so that the resulting output voltage can be optimized. Based on the background of the problems faced, this research will analyze the comparison of the output voltage of the DC-DC buck boost converter with the sepic converter on the wind power plant. This converter will be integrated in the PLTB to overcome the unstable output voltage. So it is expected to be able to overcome the problem of not fulfilling the input voltage on the load. This research uses PSIM software to simulate the efficiency of buck-boost and sepic converter circuits by comparing the output voltage produced by each converter.

2 Literature Review and Methods

2.1 Wind Energy Potential in Indonesia

Indonesia is a tropical country that consists of two seasons, dry and rainy. Every year there is an annual movement of the sun that causes a shift in the heating of the earth's surface. As a result, there is a difference in air pressure between the northern hemisphere and the southern hemisphere [5]. This difference causes monsoon winds which result in Indonesia experiencing two seasons. During the dry season, Indonesia has considerable wind energy potential. Moreover, every day the earth receives about 1.74 x 1017 W/hour of sunlight, and about 1-2% is converted into wind energy [6].

The distribution of wind speed in several regions in Indonesia shows that high wind speeds are obtained on the coast of Java, South Sulawesi, Maluku and NTT, which are 6-8m/s. Meanwhile, in other areas the average wind speed is 4.6-5.9 m/s. This potential certainly needs to be maximally utilized to meet and increase the electrification ratio in Indonesia.

Fig. 1. Wind speed map of Indonesia [3]

2.2 Wind Power Plant

Wind Power Plant is a type of power plant that utilizes wind energy to drive a pinwheel and rotate the alternator so that it can produce electrical energy [7]. The wind that drives the mill has a certain speed in the form of kinetic energy. The energy produced by the wind can be calculated by the following equation:

$$w = \frac{1}{2} pAv^2 \quad (1)$$

The equation assumes that all kinetic energy is converted entirely to electrical energy and the wheel is considered ideal.

2.3 Wind Turbine

A wind turbine or windmill is a wind-driven turbine that can be used for various purposes. The principle of the windmill used in this study is the conversion of mechanical energy from the rotation of the wheel into electrical energy generated by electromagentic induction [7]. Basically, windmills are divided into two types, namely vertical axis windmills and horizontal axes [8]. The use of this windmill is adjusted to the conditions and wind speed. So, it can be determined the type of blade used for the wheel, the size of the wheel, and other supporting frameworks so that the wheel works optimally.

2.4 DC-DC Converter

In the development of electronics, the use of direct voltage (Direct Current) has become a necessity. Thus, there are more and more variations for the conversion of DC voltage output with higher or lower output [9]. Basically there are several types of DC-DC converters. DC converters that are classified as conventional are Buck converter, Boost conventer and Buck-Boost converter. Then, the three converters were further developed into CUK converters, Sepic converters and Zeta converters. The following converter is used in this study.

1. Buck-Boost Converter

Buck-Boost converter is one type of DC converter that can produce an output voltage higher or lower than the input voltage. This converter is classified as a conventional converter which has a working principle when the switch (ON) then the current in the inductor will rise and when sakalr (OFF) then the current in the inductor will flow to the load. The ON-OFF switch time is proportional to the average load voltage, so that the average output voltage value of the load can be lower or higher than the input voltage [10].

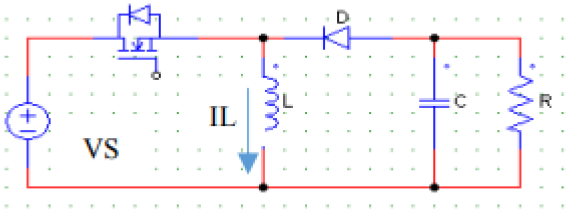


Fig. 2. Buck-boost converter circuit[11]

2. Sepic Converter

Basically, this sepic converter generates the same output voltage as buck-boost, where the output voltage can be higher or lower than the input voltage. Then, the polarity of the sepic is the same as the input voltage (non-inverting) [12]. However, this sepic converter produces smaller ripples than other converters.

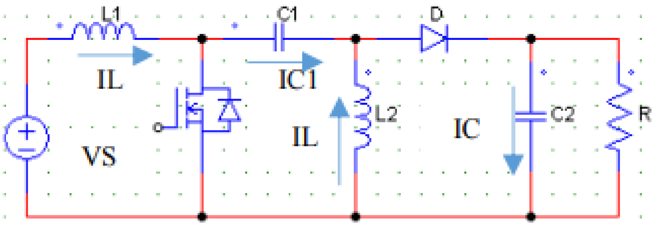


Fig. 3. Sepic converter circuit[13]

2.5 MOSFET

Mosfet is an electronic component that has a function for switches in electronic circuits. Basically MOSFET has three legs namely source, gate, drain [14]. Each leg on the MOSFET has a function including the source leg which is the leg for the flow of electricity into the MOSFET. The width of this electricity channel is regulated by the gate leg, which then the electricity will come out through the drain leg [15].

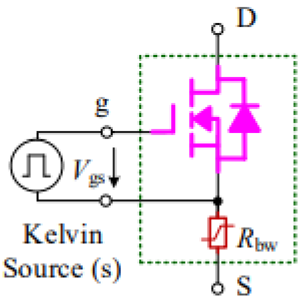


Fig. 4. MOSFET Wiring [16]

2.6 Research Flowchart

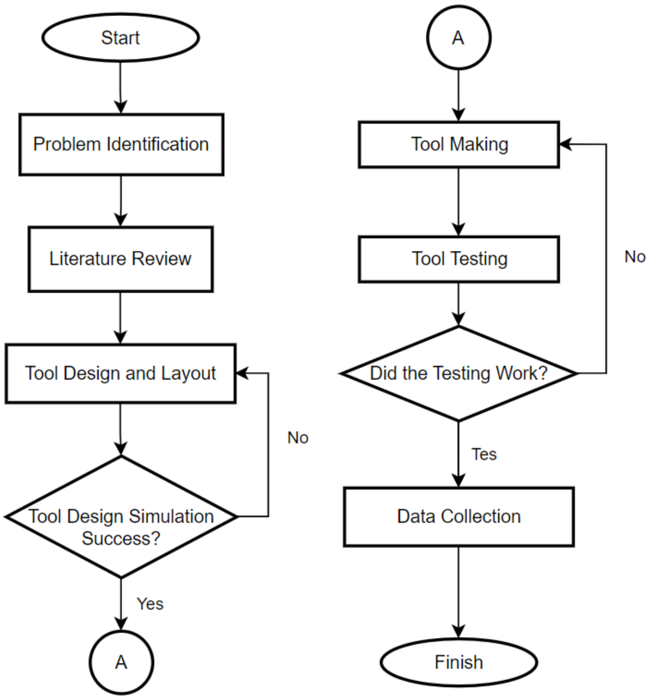


Fig. 5. Research Flowchart

The flow of this research starts from identifying existing problems to be solved. Then, a literature study is conducted to obtain a theoretical basis and solutions that can be used to overcome these problems. This literature study can be in the form of a study of problems with the same pattern, as well as innovation and development of handlers. Next, make the design and design of the tool. At this stage the design and design of the tool is made based on the literature review that has been made. Then, the design is simulated. If the tool simulation still encounters inappropriate results, recalculation is carried out on the tool design. In this study, the tool is a buck-boost converter and a sepic converter which is tested with PSIM software to get the output voltage results. These results will be compared to the efficiency in this study. Then, for further stages, this research will realize the optimal converter for wind power based on the data that has been obtained. In the final stage, data will be collected from the tools that have been made. The data can be used for further development and literature review for other research.

2.7 Component Determination

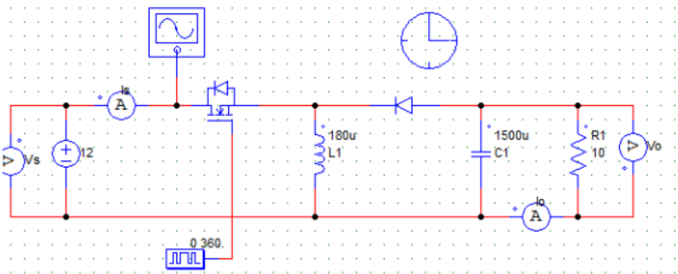
To make simulations in PSIM, component calculations have been carried out on each converter with details in the following table.

Table 1. Component value each converter

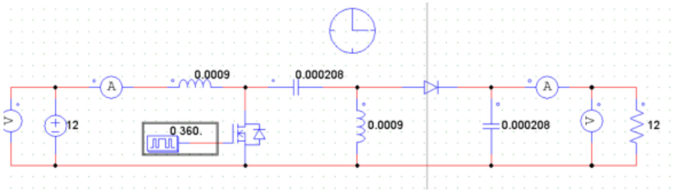
Component	Buck-Boost Converter	Sepic Converter
L1	180μH	900μH
L2	-	900μH
C1	1500μF	208μF
C2	-	208μF
R	10Ω	12Ω
MOSFET	IRF2807	IRF540
Diode	IN4148	IN4148

2.8 PSIM Circuit Design

Simulation to obtain output voltage data in this study is using PSIM software which components in table 1. Assembled in such a way based on the needs of each converter as follows.



(a)



(b)

Fig. 6. Buck-boost converter circuit (a) and Sepic converter circuit (b)

3 Result and Discussion

In this converter, an analysis of the output voltage is conducted between the buck-boost converter and the sepic converter. As a result, the difference in output voltage between the performance of both converters can be determined.

Table 2. Component Value of Each Converter

Vs	Duty Cycle	*Buck-Boost Converter*		*Sepic Converter*	
		Vout	Iout	Vout	Iout
	10	1,34	0,13	1,42	0,11
	20	3,02	0,30	3,05	0,25
	30	5,17	0 ,51	5,17	0,43
	40	8,04	0,80	8,01	0,66
	50	12,07	1,20	12	1
12	60	18,10	1,81	18,01	1,50
	70	28,14	2,81	28	2,33
	80	48,22	4,82	47,98	3,99
	90	108,27	10,82	107,56	8,96
	100	1,51x10^-5	1,51x10^-5	9,75x10^-10	15x10^-10

Based on the data obtained, it shows that both types of converters can be used for both voltage boosting and voltage bucking modes. With a 12VDC input voltage, the results indicate that both converters have a negligible difference in output voltage, as shown in the following graph.

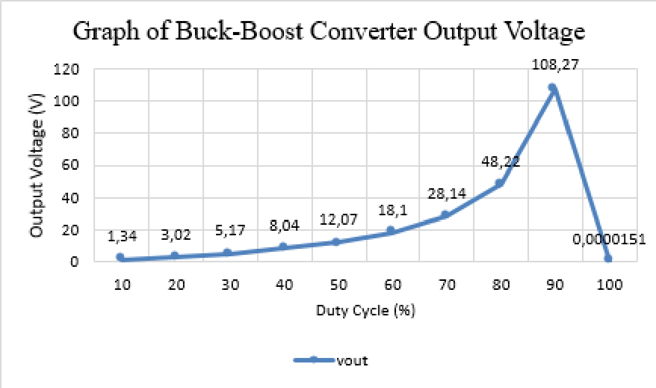


Fig.7. Graph of Output Voltage of the Buck-Boost Converter Circuit Against Duty Cycle

It can be observed from the data in the graph that the buck-boost converter operates in voltage reduction mode from a duty cycle of 10% to 40%. This can be seen as the input voltage, originally at 12VDC, drops below 12VDC. At a 10% duty cycle, the resulting output voltage is 1.34V. Then, at a 20% duty cycle, the output voltage is 3.02V. Subsequently, at a 30% duty cycle, the output voltage is 5.17V. Finally, for voltage reduction, at a 40% duty cycle, the output reaches 8.04V.

On the other hand, from a duty cycle of 50% to 90%, the buck-boost converter operates in voltage boosting mode. This can be seen as the input voltage, originally at 12VDC, increases above 12VDC. At a 50% duty cycle, the resulting output voltage is 12.07V. Then, at a 60% duty cycle, the output voltage is 18.10V. Subsequently, at a 70% duty cycle, the output voltage is 28.14V. Finally, for voltage boosting, at a 90% duty cycle, the output reaches 108.27V.

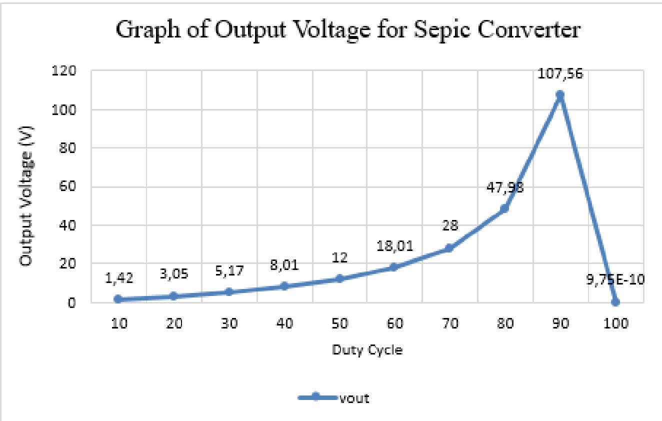


Fig.8. Graph of Output Voltage of the Sepic Converter Circuit Against Duty Cycle

Then, in the Sepic converter output voltage graph, it is evident that from a duty cycle of 10% to 40%, the Sepic converter operates in voltage reduction mode. This is noticeable as the input voltage, originally at 12VDC, drops below 12VDC. At a 10% duty cycle, the resulting output voltage is 1.42V. Then, at a 20% duty cycle, the output voltage is 3.05V. Subsequently, at a 30% duty cycle, the output voltage is 5.17V. Finally, for voltage reduction, at a 40% duty cycle, the output reaches 8.01V. At a 50% duty cycle, the input voltage equals the output voltage, which is 12VDC. Then, from a duty cycle of 60% to 90%, the Sepic converter operates in voltage boosting mode. This is evident as the input voltage, originally at 12VDC, increases above 12VDC. At a 60% duty cycle, the resulting output voltage is 18.01V. Then, at a 70% duty cycle, the output voltage is 28V. Subsequently, at an 80% duty cycle, the output voltage is 47.98V. Finally, for voltage boosting, at a 90% duty cycle, the output reaches 107.56V.

Based on this data, both the buck-boost converter and the Sepic converter have operated according to their working principles, which involve both voltage boosting and voltage reduction. However, the research results indicate that the buck-boost converter can handle voltage conversion more effectively than the Sepic converter. This is evident from the simulation data, where from a 40% to 50% duty cycle, the output voltage of the buck-boost converter is higher than that of the Sepic converter. Nevertheless, based on previous research, the Sepic converter produces smaller ripples in the output waveform of the conversion results. To further explore this aspect, additional research is required. Both types of converters can be used in photovoltaic power plants (PLTB) and can help optimize generator performance.

4 Conclusion

The conclusions that can be drawn from this research are as follows. Buck-Boost converters and Sepic converters can be used to optimize the output voltage of Wind Power Plants with an input voltage of 12VDC. In this study, the output voltage results of the Buck-Boost converter were higher than the Sepic converter. So the buck-boost performance is better than the sepic converter. The duty cycle or PWM setting affects the resulting output voltage. Where the higher the duty cycle percentage value, the higher the output voltage produced by each converter. Further research needs to be carried out to prove and analyze the ripples in each converter so that it can be used to develop converter technology.

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