ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

DEVELOPMENT OF BUCK CONVERTER BASED FUZZY LOGIC CONTROL IN SMALL SCALE WIND TURBINE SYSTEM IMPLEMENTED IN EAST-JAVA

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ABSTRACT

Energy production from the wind turbines in order to function at its optimum should be controlled. Electrical power products generated turbine depends on the wind speed variations in wind lading. Voltage power products with varied, so before it was used or stored energy in the battery voltage level must be maintained. In this study constructed buck converter power electronics in the form of a fuzzy logic -based voltage control in wind turbines. Buck converter is a type converter lossless transition is relatively large compared to linear converter type. This process is carried out at voltage stabilization. Sugenp type fuzzy logic works with input error and delta error, the value of output in the form of crips for generating a signal pulse width modulation (PWM). Performance of the fuzzy logic -based converter has been built to function properly. With HSIL indication that the test has been done. With the value of the turbine generator V setpoint input 2 volts, the measuring error of 0.8 %. At the advanced test with 4 volt V setpoint input has an error of 1.3 %, for V input with setpoint 6 volt has an error 0.5 % and the setpoint input V 8 volts produces kesalhan 0:22 %

Keywords: Wind Turbine, PWM, Fuzzy logic, Buck converter

INTRODUCTION

The geographical position of Indonesia as a tropical country located around the equator caused by the different characteristics of the wind lading wind characteristics in the countries of sub-tropical. Sub-tropical countries have much use wind power as a major supplier of electrical energy. Characteristics of the wind lading as a relatively high wind speeds and stable compared within Indonesia. Differences in these characteristics lead to electrical energy which is built in Indonesia through the Wind Energy Conversion System (Skea) is still relatively small. Parameters that lead to non optimal electrical energy generation from wind turbines in Indonesia is caused by the variable voltage power output is relatively small and volatile [1].

Development of DC-DC power onverter transitional type or DC Chopper to keep the output voltage of DC input and a relatively large variations mamapu adjust to variations in load demand. Power input of DC-DC converter that is sourced from the DC power has varied input voltage. Buck converter is built to function stabilizes voltage by lowering the output voltage is lower without losing power is relatively large. DC output voltage to be achieved is expected to reach a certain level. Dilbuat mengaturan by linking interval between the input and output sides of the buck converter circuits. Components used to carry out the liaison function is switches (solid state electronic switches) comprising Thyristor, MOSFET, IGBT, GTO [2].

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

Control system is built by using fuzzy logical algorithm that is an alternative to intelligent control system that is relatively easy. In this case does not require a mathematical model of the system, but still effective and efficient for stable system response. In this study Converer buck duty cycle is set to the PWM switch is related to the amount coming out of the microcontroller. Done with programming techniques based on the principle of fuzzy logic control. The resulting changes in the output voltage can be regulated turbine generator by varying the amount of PWM, which is used for switching the converter process. Operational voltage range of this system is represented by the value of the specified set point thereafter held by the fuzzy logic control system [3].

MATERIALS AND METHODS

Wind energy generation is built on the principle of wind kinetic energy changes before and after passing through the wind turbine. When the wind drift on the wind turbine, the wind speed will decrease. Consequently kinetic energy also decreased related to wind speed changes. Decrease in kinetic energy is converted into mechanical energy is used to rotate the blade. Great mechanical power generated by the wind turbine is defined in equation1.

With ρ is the density of air (kg/m3), Cp coefficient of performance of a wind turbine, a wind turbine sweep of the area (m2), and V1 is the wind speed before passing wind turbine (m / s). From the equation above it can be concluded that the power that can be converted by Skea highly dependent on wind speed.

$$P_m = \frac{1}{2} \rho C_p A V_1^3 \quad (1)$$

Relationship of wind speed and wind power production can be written in equation 2, the wind speed has a role in Wind Energy Conversion System. [4].

$$P_{rated} = (V/V_{rated}) \times P_{WT\,(rated)} \quad (2)$$

Converter DC-DC switching mode, to better understand the major types of transition, following the principles described DC-DC power conversion of linear type as shown in Figure1. [5].

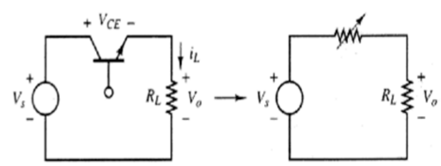


Figure 1. Type Converter circuit switching [5]

On the type of converter switching transistor seen that function as electronic switches can function open (off) and closed (on). When the switch is working ideally, the state of the switch is closed; the output voltage will be equal to the input voltage, where as if the switch is open, the output voltage will be zero. Thus the output voltage will have a pulse shape as shown by in Figure 2.

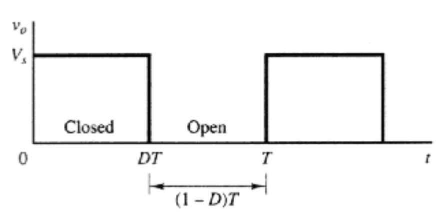


Figure 2. Output voltage signal [5]

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

Value of the average output voltage DC component can be derived byequation3, as follows.

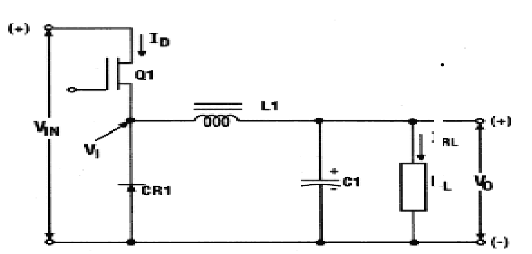
$$V_o = \frac{1}{T}\int_0^T(t)dt = \frac{1}{T}\int_0^{DT} V_{in}dt = V_{in}D \quad (3)$$

From equation 3 seen that the DC output voltage value can be set by adjusting the parameters of D. The parameter D is known as the duty ratio is the ratio between the lengths of time the switch is closed (tons) for the period T of the output voltage pulse. with0≤D≥1. Parameter f is the switching frequency (switching frequency) is used to operate the switch.

$$D = \{t_{on} / (t_{on} + t_{off})\} = t_{on} / T = t_{on} .f \quad (4)$$

Differences in the type converter is linear and the type of transition, the converter types witching power absorbed no transistor which serves as a switch. When the switch is closed there is no voltage at the transistor falls, while at the time the switch is opened, there is no electric current flowing. All the power absorbed by the load, so the near-perfect power efficiency and power loss is relatively small. Basic buck converter circuit is shown in Figure3. In the circuit, the output voltage value is lower or equal to the input voltage. In addition, if the operation of the current flowing through the inductor is always greater than zero (CCM –Continuous Conduction Mode), then the relationship between the output voltage to the input voltageindicatedequation5.

$$V_o = D. V_{in} \quad (5)$$



Gambar 3. Rangkaian Buck Converter [5]

Gains on conferter buck configuration is to have high efficiency, the circuit is simple, do not require transformers, switch component stress levels on a low, ripple on the output voltage is low so the filter required is relatively small. Deficiencies found is the lack of isolation between the input and the output, only one output is generated, and a high level of ripple on the input current. Buck method often used in system applications that require small-sized systems.

Pulse Width Modulation (PWM) is a method of manipulation of the pulse width in a constant period to get the average voltage is different. PWM signal is shown in Figure4. There are three different PWM signal, the signal is shown at the top PWM signal with a duty cycle of 20%, meaning that the signal on for 20% of the signal period and for 80% off. Other images show that the signal with a duty cycle of 50% and 90%. The third PWM signal generating analog signals are different. Example if the supply voltage of 9V and 20% duty cycle, it produces a voltage1.8V.

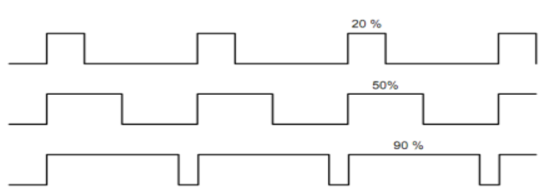


Figure 4. PWM signal with a duty cycle variation [5]

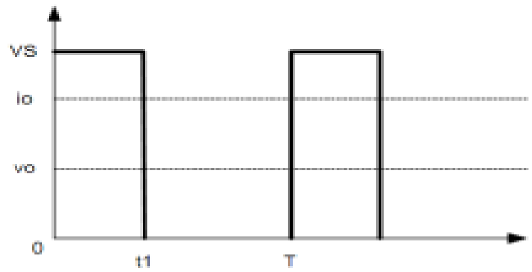


Figure 5. PWM signal [5]

RelationshipPWMvoltagesourceandvoltageoutputslumberingindicatedbyequation6.

$V_0 = (t_1 / T)\ V_s$ (6)

V_0 : Output voltage (Volt)

V_s : PWM puls voltage (Volt)

t_1 : Period of hight puls (detik)

T : Period of puls (detik).

DC generator is a device that converts electrical machine dynamic mechanical energy into electrical energy. DC generators produce direct current. DC generator consists of several types based on the series winding excitation of the magnet or amplifier anker, type DC generator consists of a separate amplifier Generator, Generator shunt and compound. DC generators generally made using permanent magnet rotor with 4 - pole, digital voltage regulators, and protection against overload, starter excitation, rectifiers, bearing and generator house or chassis, as well as parts of the rotor [3]. DC generator consists of two parts; the stator is the stationary part of the machine, and the parts of the rotor, which is part of a rotating machine. Part consists of a stator frame motors, the stator windings, charcoal brushes, bearings and terminal box. While the rotor consists of a commutator, winding rotor, fan rotor and the rotor shaft. The working principle of direct current generator is based on Faraday's law ditunukkan equation 7.

$E = - N\, d\varphi / dt$ (7)

N: the number of windings

φ: magnetic flux

e= voltage induced, GGL (Motion Style Electric

RESULTS AND DISCUSSION

Development of Buck Converter Based Fuzzy Logic Control, in order to avoid loss of the buck converter in real manufacturing begins with the simulation with ISIS 7.4 software. Design with simulation results performed with simulation until deperoleh best output voltage, then performed in accordance with the design of the actual implementation. Buck converter consists of a divider circuit that functions as a voltage sensor with a range that produces maximum output, maximum voltage required by 5 volts, the output voltage of the voltage divider representing each input buck converter which is then converted to digital signals by the microcontroller through ADC features. Microcontroller reads ADC signals which will give the command to switch according to the duty cycle of the PWM signal.

Fuzzy Logic Control on the inverter and control positions in the research buck converter is shown by the block diagram in Figure8.

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

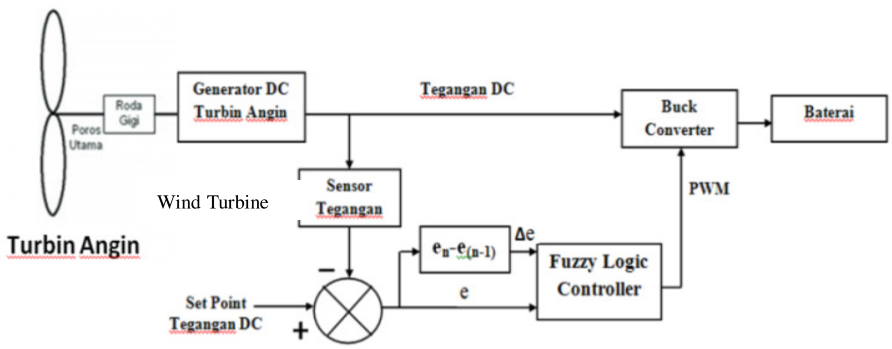


Figure 8. Block diagram of fuzzy logic control in buck converter

In the design of fuzzy systems using Sugeno method, reasoning with Sugeno method is similar to Mamdani reasoning. Output (consequent) is not a fuzzy set system, but rather a constant or linear equations. This method was introduced by Takagi-Sugeno Kang1985. Fuzzy system is constructed consisting of two input fariabel the error (e) and delta errors (de) and the results of akelurancrips value to generate the PWM signal. Are shown in Figure 9.

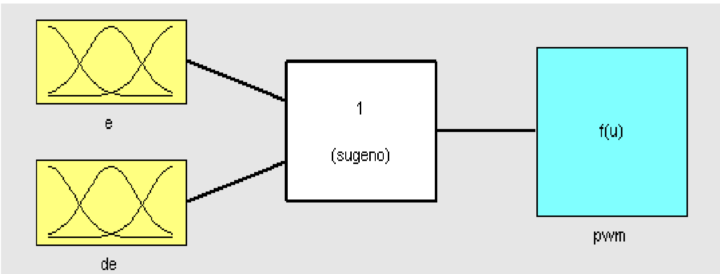


Figure 9. Fuzzy systems are built

Fuzzy fikasi in the design of the controller is to change the value of the ADC into fuzzy input values . Formation of fuzzy sets is done by dividing the input members who become fuzzy system inputs , input fuzzy system consists of two variables: error (e) and delta errors (de) , the error is defined as the result of a reduction in the value of the setpoint with the actual voltage sensor further reads the converted a digital scale by ADC . Keanggautaan input error function is divided into seven sections. Triangular membership function with value range besaranya ADC values to be programmed. Programming is done on the microcontroller with 10 -bit value (0-1023). Formation of input fuzzy sets in the form of error and the second input to the input of fuzzy system is a delta error (de) , the actual error margin delta error (error to - n) with error at the previous condition (error to n - 1) , which is used in a range of membership functions de at the upper limit is 1023 (1023 is reduced to 0) and the lower limit is -1023 (0 minus 1023). Membership functions de divided into three parts as shown in Figure 10-11.

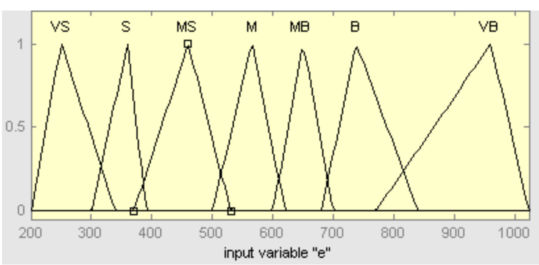


Figure 10. Membership function of error

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

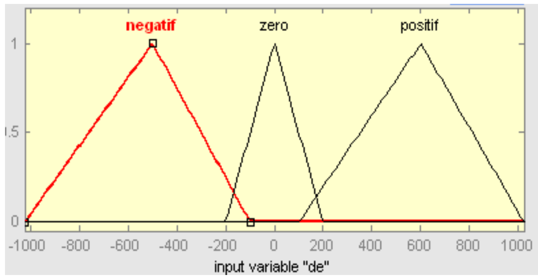


Figure 11. Membership function of delta error

The rule base is constructed from converter design, which has 21 rule base shown in Table 1.

Table 1. Rule base of Fuzzy system

e/de	*N*	*Z*	*P*
VS	pwm1	pwm1	pwm2
S	pwm1	pwm2	pwm3
MS	pwm2	pwm3	pwm4
M	pwm3	pwm4	pwm5
MB	pwm4	pwm5	pwm6
B	pwm5	pwm6	pwm7
VB	pwm6	pwm7	pwm7

The table above shows the reading of the rule base as follows,

IF error IS VS AND delta error N THEN pwm1

IF error IS S AND delta error Z THEN pwm2

IF error IS MS AND delta error P THEN pwm4

IF error IS M AND delta error Z THEN pwm4

IF error IS MB AND delta error Z THEN pwm5

IF error IS B AND delta error P THEN pwm4

IF error IS VB AND delta error Z THEN pwm4

and so on

The rule base that has been done obtained fuzzy rule viewer system Figure 12.

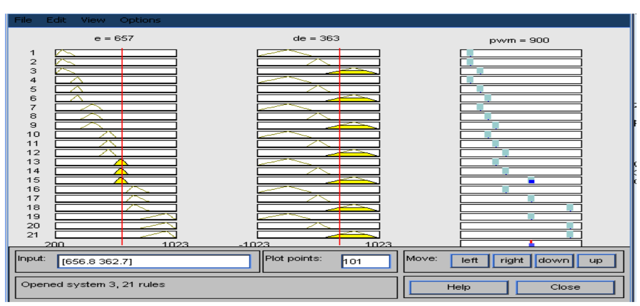


Figure 12. Rule of viewer fuzzy system

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

Output fuzzy system declared value crips to call PWM amount spent on pin (D.4) with a duty cycle of PWM value divided by the value oftopOCR1A. Defuzzy aggregation process and to obtain firm value output M fuzzy rules is done using the mean weight equation 8.

$$Z = \frac{\sum_{k=1}^{M} \alpha_k z_k}{\sum_{k=1}^{M} \alpha_k} \qquad (8)$$

DISCUSSION

Development of Fuzzy Logic -based programming algorithm created in AVR software using C language programming with the core principles of fuzzy logic have been designed previously , this algorithm will then be planted on the microcontroller ATMEGA 16 via downloader with kazama software . The following workflow is applied to the microcontroller programming , Testing Buck Converter , done by testing the buck converter fuzzy logic -based control , Generate output voltage varies with seven variables; 3.18; 4.87; 6.32; 7.86; 9.36; 10.97, and 14.7 volts . Slew presents a generator output voltage changes due to changes in wind speed. DC generator power output testing is done by collecting data turbines that generate power are not as expected. Maximum voltage of 3.19 volts and a current of 0.23 amperes. Wind turbine and generator rotating DC maximum in the range of 132-147 rpm for wind speed of 7 m / s. Flowchart power output measurements of wind turbine generator is shown in Figure 13.

Data collection was shown in Table 2. Performed in the range of each variable and not done because of the limitations of measuring devices that measure in series between voltage, electric current and pulse per second (pps). In addition it is not possible the achievement of plant wind turbines can rotate constantly, so that the voltage, current or power in a state of fluctuation pp sun read able within a certain range.

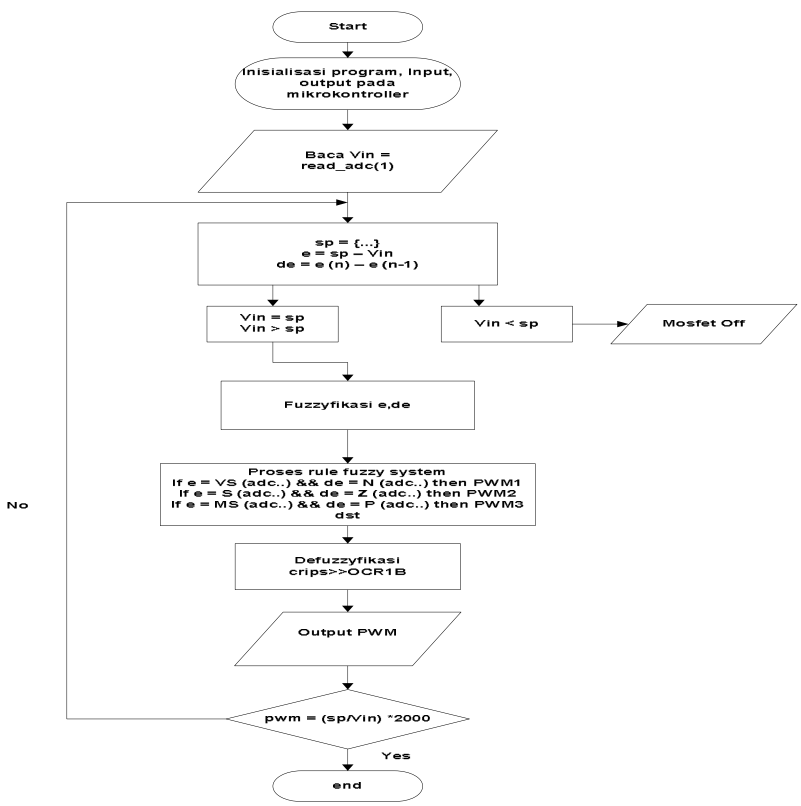


Figure 13. Flow chart programming test voltage and current

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

Tabel 2. Pengujian tegangan dan arus listrik keluaran generator

pps	*rpm*	*V (volt)*	*I (mA)*
0 - 11	0 - 33	0 - 0,61	0 - 0,19
12 - 30	36 - 90	0,63 - 1,78	0,19 - 0,21
32 - 36	96 - 108	1,79 - 1,98	0,19 - 0,22
38 - 42	114 – 126	2 - 2,19	0,19 - 0,23
44 - 49	132 - 147	2,20 - 3,19	0,19 - 0,23

Buck Converter testing performed by measuring the output voltage of the generator when the wind turbine blade having rounds in the range of 132-147 rpm , the voltage generated at this rpm produces a required minimum input voltage buck converter about 2 volts , and be done with speed variation below the rpm limit the voltage and current generator will be exhausted prior to the reduction process , because the voltage generated is at the limit of only produces a voltage below minimum voltage requirements buck converter . This test is done to control the voltage by the generator in order to lower the input voltage reaches the setpoint value 2 volts. The following response measurement data displayed buck converter output voltage Figure 14-15. By Wind fluctuated 2.20 to 3.19 volts with an average error of 0.8 % response system? Testing current relationship is shown in Figure 15. Electric current loss of 0.15 to 0.17 mA load factor due to electronic components buck converter circuits.

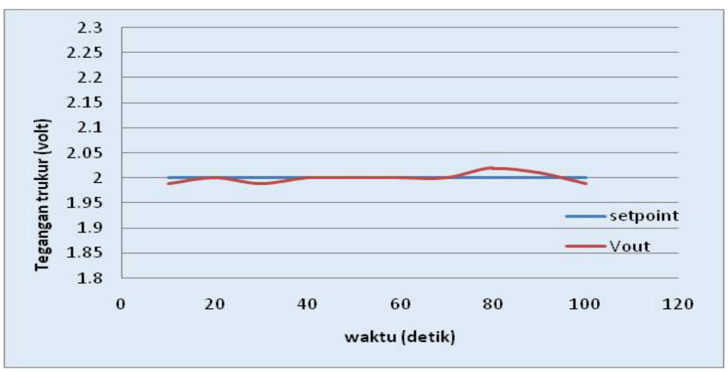


Figure 14. Response of voltage test in buck converter wind turbine

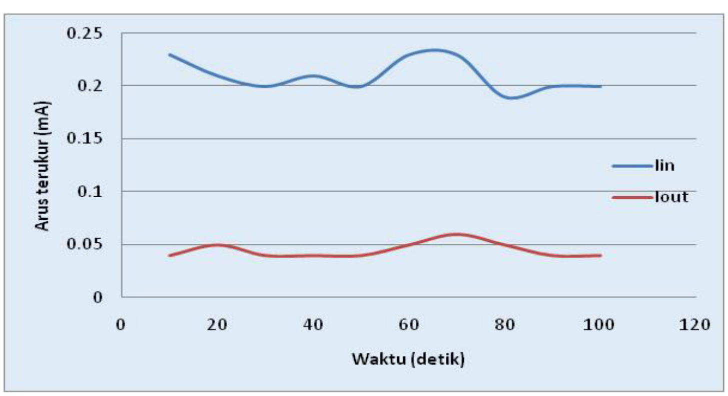


Figure 15. Response test of buck converter current in wind turbine

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

Table 3.Testresults of Buck Converter with Voltage Set point variation

Set Point (Volt)	*Vin (Volt)*	*Error rate (%)*	*Current Loss (mA)*
2	14.07	3.80	0.89
	10.97	4.70	0.61
	9.36	9.36	0.51
	7.86	7.86	0.65
	6.32	6.32	0.23
	4.87	4.87	0.20
	3.18	3.18	0.16
4	14.07	3.80	0.64
	10.97	3.90	0.46
	9.36	2.85	0.39
	7.86	3.70	0.25
	6.32	1.55	0.14
	4.87	1.35	0.25
6	14.07	1.55	0.60
	10.97	2.70	0.32
	9.36	1.70	0.09
	7.86	0.80	0.01
8	14.07	0.22	0.53
	10.97	1.20	0.21
	9.36	2.45	0.30

CONCLUSION

Based on the experiments, it can be concluded, has successfully designed and built a prototype wind turbine with blade rotation speed of 132-147 rpm, which produces power voltage the range 2.20 to 3.19 volts and the current 0.19 to 0.23 mA and has successfully built prototype buck converter for wind turbines with a set point value of 2 volts at maximum rpm condition have an average error of 0.8 % voltage. Testing has been performed buck converter with input voltage (Vin) with a voltage of 3.18 variation; 4.87; 6.32; 7.86; 9.36; 10.97, and 14.7 volts produces output voltage error on average with buck converter fuzzy

ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 2 No. 4 December 2013

logic control of 2.8 % to 2 volts set point; 2.9 % to 4 volts set point; 1.3 % for set point 6 volts, and 0.5 % for 8 volt set point. There is a loss of electricity on average for each process control or voltage drop in the buck converter of 0:36 mA and fuzzy logic system that has been built as a whole can function as a voltage controller with PWM switches in buck converter with an error response < 5 % .

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