Australian Journal of Basic and Applied Sciences, 11(11) August 2017, Pages: 79-87

AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

Development of Power Electronics ,Buck Boost Converter, Based PI-PID Control On Horizontal Wind Turbine Generation, For Low Rate Wind speed

[1]Ali Musyafa, [2]Ivan Rachman Gustawan, [3]M.Khamim Asy'ari, [4]Andi Rahmadiansyah, [5]Ronny Dwi Noriyati,

[1]*Associate Professor, Department Of Engineering Physics, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.*
[2]*Student, Department Of Engineering Physics, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.*
[3]*Student, Department Of Engineering Physics, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.*
[4]*Lecturer, Department Of Engineering Physics, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.*
[5]*Senior Lecturer, Department Of Engineering Physics, Sepuluh Nopember Institute of Technology, Surabaya, East Java, Indonesia.*

Address For Correspondence:
Ali Musyafa', Department of Engineering Physics, Faculty of Industrial Technology, Sepuluh Nopember Institute Of Technology,
Phone: 62-31-5966138/5947188; E-mail: musyafa@ep.its.ac.id, Kampus ITS Keputih, Sukolilo, Surabaya – Indonesia, 60111.

ARTICLE INFO

Article history:
Received 18 June 2017
Accepted 28 July 2017
Available online 20 August 2017

Keywords:
Buck boost converter, PI, PID, Ziegler-Nichols

ABSTRACT

For the supply of electric power from a wind turbine having a direct voltage (dc), it takes conversion of dc voltage at a certain level input to a dc voltage level at a certain output (lower or higher voltage level) such as dc-dc converter with buck boost converter type . To keep the output voltage level of the buck boost converter in accordance with the desired value (set point) in accordance with the applied, it needs a control system (Devais) that can be applied to the system, the control of PI and PID. Modeling and design intent of buck boost converter system implemented control mode PI and PID. Determination of PI-PID control parameters using Ziegler-Nichols method. The design result of PID controller gain shows that the value of Kp = 0,0027; Ti = 0.0009; And Td = 0,00023; In the control design PI obtained value Kp = 0.00205; And Ti = 0.0015;. The result of system test and buck boost converter analysis with PI control system has the following response: When system is given input = 10 V, it has the best stability for set point value = 28 V has maximum overshoot value (Mp) = 0, settling time (Ts) = 0.33 seconds, peak time (Tp) = 0, rise time (Tr) = 0.32 sec and steady state error (Ess) = 0.12 V. By Performace test, the PID control system on buck boost converter system using input 30 Volt set point, has the best stability performance with maximum overshoot value (Mp) = 7 V, settling time (Ts) = 0.09 seconds, peak time (Tp) = 0.017 seconds, rise time (Tr) = 0.01 sec and Error steady state (Ess) = 0,1 V.

INTRODUCTION

In the development of science and technology, the concept of electronics and control plays an important role in electric power supply systems with direct voltage (dc). Which is obtained from dc voltage input conversion into lower or higher dc voltage output. This dc voltage conversion is called a dc-dc converter. The development of electronics devices used to store current electricity such as batteries or batteries today has a relatively small size. Electronic devices that can change the value of dc-dc electrical voltage much needed in new renewable energy generation.

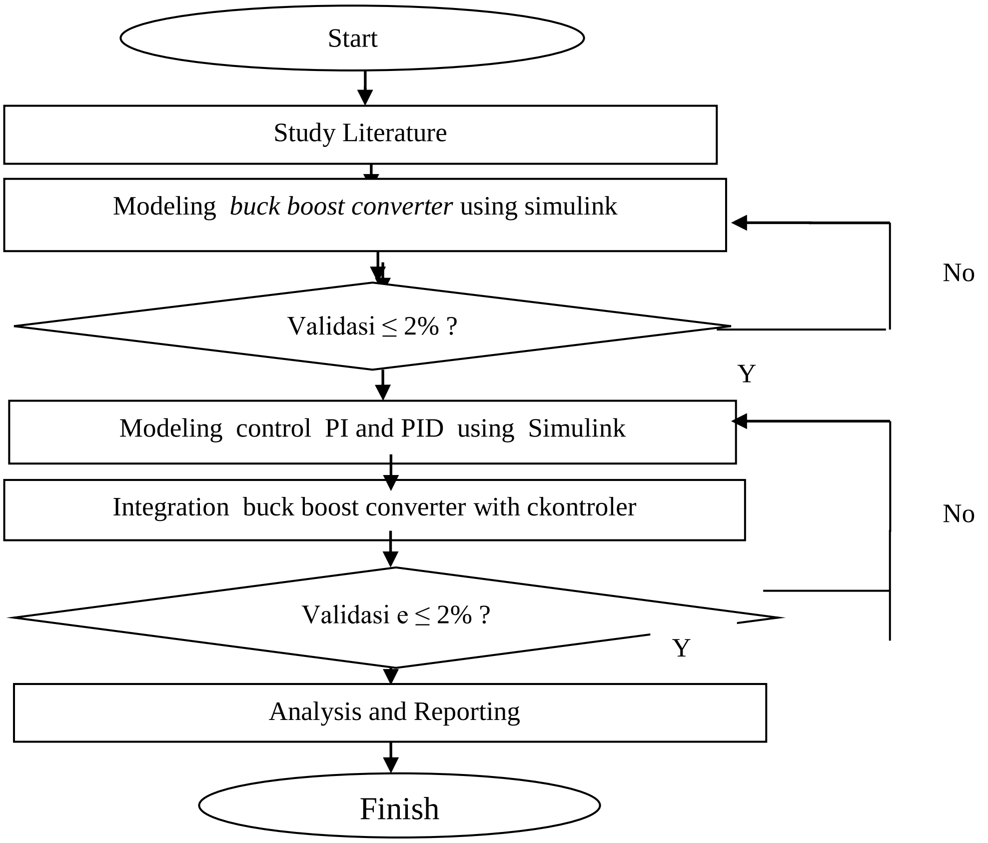
Buck boost converter is a direct current converter device that can change the product of system output voltage larger or smaller than input voltage, by adjusting pulse width (pulse width) duty cycle. To set the output voltage of the buck boost converter in accordance with the specified or set point that has been determined, it takes a simple control strategy and can be applied to the system, such as PI control and PID. Both control

To Cite This Article: Ali Musyafa, Ivan Rachman Gustawan, M.Khamim Asy'ari, Andi Rahmadiansyah, Ronny Dwi Noriyati., Development of Power Electronics, Buck Boost Converter, Based PI-PID Control On Horizontal Wind Turbine Generation, For Low Rate Wind speed. ***Aust. J. Basic & Appl. Sci.,*** *11(11): 79-87, 2017*

strategies will be implemented and compared their performance values, whichever is better. In this study designed and implemented both methods to determine the performance and performance of PI and PID control systems applied to buck boost converter. By varying the value of the input voltage and observing the output voltage generated will be monitored whether the output value has been in accordance with the specified set point which can further be applied to the power plant as in the wind power plant.

MATERIALS AND METHODS

The research activity here follows the process sequence as shown in the flow diagram shown in Figure 2.1. as follows:



Gambar 1: Flowchart Penelitian

The control system block diagram of the buck boost converter is shown in Figure 2.2. As follows:

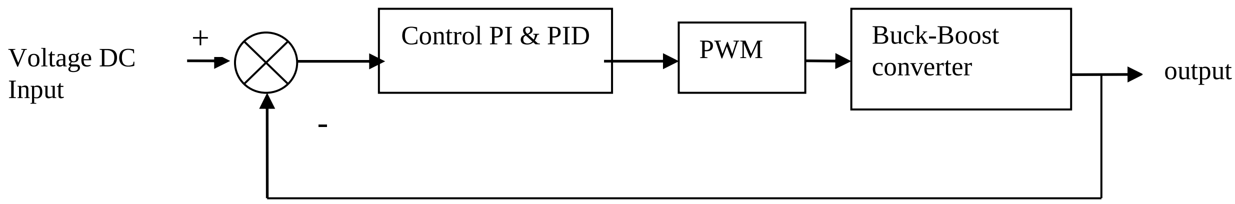


Fig. 2: Block diagram of Control Converter system

A. Buck Boost Converter System Design for Model Simulation

2.1. Buck Boost Converter Modeling:

The development of buck boost converter is influenced by the voltage of the wind turbine generator which always change based on the change of wind speed. A very converter RLC value calculation is required to design a buck boost conterver system. The buck boost converter image is shown in Figure 3.

Australian Journal of Basic and Applied Sciences, 11(11) August 2017, Pages: 79-87

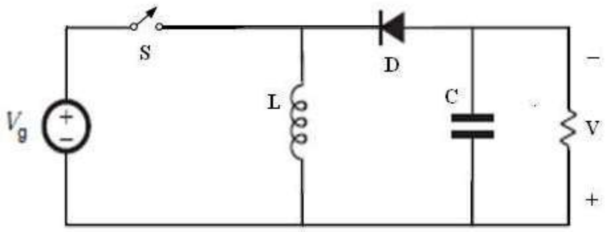


Fig. 3: *Buck boost converter.*

For the value of the voltage produced by the installed wind turbine, if the voltage value is in the arrange (10-34.9) V, and the current is 2.9 A, with the set point 28 V setting, the desired 10% ripple value, the voltage tolerance Which is allowed at 3%, the converter efficiency built at least 85% and the switching frequency is 31372.6 Hz [3] (the use of this switching frequency using the switching frequency approach on the microcontroller) then the RLC values are then determined by the following calculation;

- Determination of duty cycle value [4], by calculating duty cycle using equation 1.

$$\frac{V}{Vg_{minimal}} = \frac{D}{1-D} \quad \rightarrow \frac{28}{10} = \frac{D}{1-D} \qquad (1)$$

28(1-D) = 10D → 28-28D = 10D → 28 = 10D+28D → 28 = 38D → D = 28/38 → D = 0,74

- Looking for resistor values using 2 [4].

R = Vo/Io → R = 28/2,9 → R = 9,655 Ω (2)

- Inductor value is calculated using equation 3 Nilai [4]

L min = (1-D) x R → Lmin = $((1-0{,}74)^2/2x31372{,}6)$ x 9,655 → Lmin = 0,653/62745,2

L min = 1,041 x 10^{-5} atau 10,41 µH (3)

- The value of the capacitor is calculated using equation 4,

$$C = \frac{28 x}{9{,}655 x 0{,}1} \qquad (4)$$

C = 2,28016 x 10^{-3} atau 2280,16 µF

The transfer function of the buck boost converter model is as follows [4]:

$$G(s) = \frac{V\left(1-\frac{sDL}{D'^2R}\right)}{D\left(D'^2+\frac{sL}{R}+s^2LC\right)} \qquad (5)$$

If the values of R L C and D are included in equation 5, then they are obtained;

$$G(s) = \frac{-1{,}751\left(10^{-4}\right)s+28}{1{,}757(10^{-8})s^2+7{,}977(10^{-7})s+0{,}0944}$$

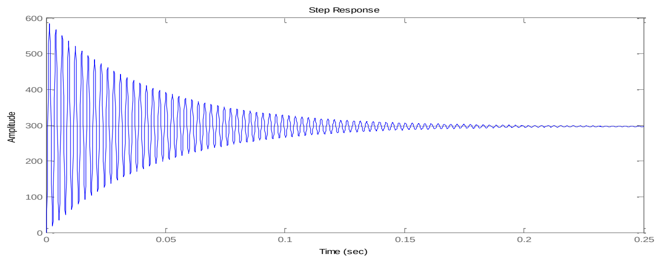


Fig. 4: Open Loop Response Buck Boost Converter.

2.2. Control System Modeling:

In system design, the type of control that is built is the control mode of PI and PID. Mathematically this control mode can be written as follows:

$$Gc(s)PI = Kp\left(1+\frac{1}{T_i s}\right) \tag{6}$$

$$Gc(s)PID = Kp\left(1+\frac{1}{T_i s}+T_d s\right) \tag{7}$$

Determination of Kp, Ti, Td Parameters on Buck Boost Converter voltage control system for PID control mode using Routh Hurwitzh method. In this control system the voltage used in the control system and subsequently used to determine the value of PID elements which include the value of Kp, Ti and Td. Furthermore, the quantities are used to tuning the buck boost converter system as follows;

$$G(s) = \frac{Kp\left(1+\frac{1}{Ti(s)}+Td(s)\right)(-1{,}751(10^{-4})s+28)}{1+Kp\left(1+\frac{1}{Ti(s)}+Td(s)\right)(1{,}757(10^{-8})s^2+7{,}977(10^{-7})s+0{,}0944} \tag{8}$$

The parameters Ti and Td can be ejected as equation 8, to be;

$$G(s) = \frac{Kp(-1{,}751(10^{-4})s+28)}{1+Kp(1{,}757(10^{-8})s^2+7{,}977(10^{-7})s+0{,}0944}$$ atau

$$G(s) = \frac{(-1{,}751(10^{-4})Kps+28Kp}{(1{,}757(10^{-8})s^2+(7{,}977(10^{-7})-1{,}751(10^{-4})Kp)s+(0{,}0944+28Kp))}$$, so

The system characteristic equation becomes:
$1{,}757(10^{-8})\ S^2 + (7{,}977(10^{-7})-1{,}751(10^{-4})Kp)\ S + (0{,}0944+28Kp) = 0$
By following the rules of routh-hurwitz, the critical Kp value (Kcr) can be determined as follows:

Table 3: Criteria routh hurwitz PID

S^2	$1{,}757x10^{-8}$	(0,0944+28kp)
S^1	$(7{,}977x10^{-7} - 1{,}751x10^{-4}kp)$	
S^0	(0,0944+28kp)	

0,0944+28kp > 0 → 28Kp > -0,0944 → Kp < 0,0944/28 → Kp < $3{,}3714x10^{-3}$, And the limit value of Kp can be taken from S1, then S^1 , maka $7{,}977x10^{-7}-1{,}751x10^{-4}$ Kp> 0 → $-1{,}751x10^{-4}Kp > -7{,}977x10^{-7}$ →
Kp > $-7{,}977x10^{-7}/ -1{,}751x10^{-4}$ → Kp > $4{,}555682467x10^{-3}$ Jadi nilai
Kp → $4{,}555682467x10^{-3} <$ Kp < $3{,}3714x10^{-3}$

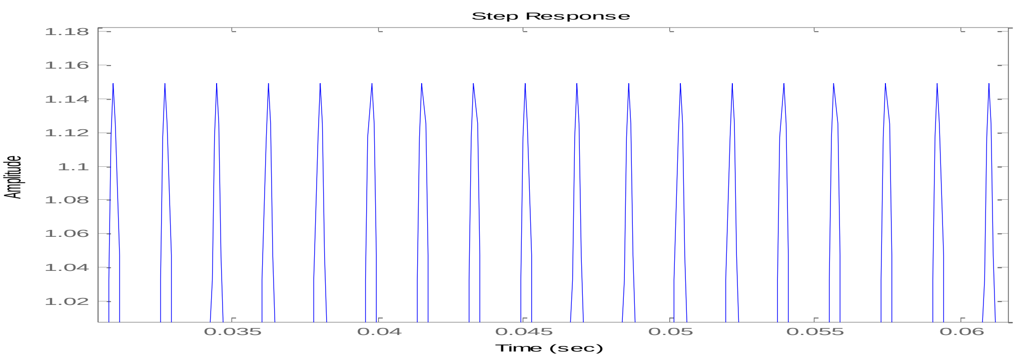


Fig. 5: Ultimate gain at Kp = 0.0046

Based on the calculation of routh hurwitzh method, the critical KP system value (Kcr) is 4.555682467x10-3. Then calculated the Pcr value by calculating the distance from peak to peak is shown Figure 5. The Pcr value is 0.0018. In order to do so, tuning with the control parameters obtained under Table 4 can be obtained as follows:

Table 4: Determination of PID parameters by ziegler-nichols method

Control Mode	Kp	Ti	Td
P	0,5 Kcr	∞	0
PI	0,45Kcr	$\frac{1}{1,2}$ Pcr	0
PID	0,6 Kcr	0,5 Pcr	0,125 Pcr

Tuning PID parameters Kp, Ti and Td are:
Kp = 0,6 x $4,555682467x10^{-3}$ → $2,73340848x10^{-3}$
Ti = 0,5 x 0,0018 = 0,0009
Td = 0,125 x 0,0018 = 0,000225
Tuning PI parameters Kp, and Ti are:
Kp = 0,45 x $4,555682467x10^{-3}$ = 0,00205005711
Ti = 0,83 x 0,0018 = 0,001494
If the PID tuning value is entered into the control system, the values of P, I and D are:

$$Gc(s)PID = Kp\ (1+\frac{1}{Ti(s)} + Td(s))$$

P = Kp = $2,73340848x10^{-3}$
I = Kp/Ti = $2,73340848x10^{-3}$/0,009 = 3,037120533
D = KpTd = $2,73340848x10^{-3}$ x 0,00225 = $6,15016908x10^{-7}$

For PI control values are as follows:

$$Gc(s)PI = Kp\ (1+\frac{1}{Ti(s)})$$

P = Kp = 0,00205005711
I = Kp/Ti = 0,00205005711/0,01494 = 0,137219351
After obtaining the value of duty cycle, resistor, inductor, capacitor and value of control of PI and PID, it can be made buck boost converter in simulink.
Buck boost converter equipped with PID or PI control mode is shown by Figure 6. The output voltage of the wind turbine system is then forwarded to the control system without delay and has a gain value of = 1.

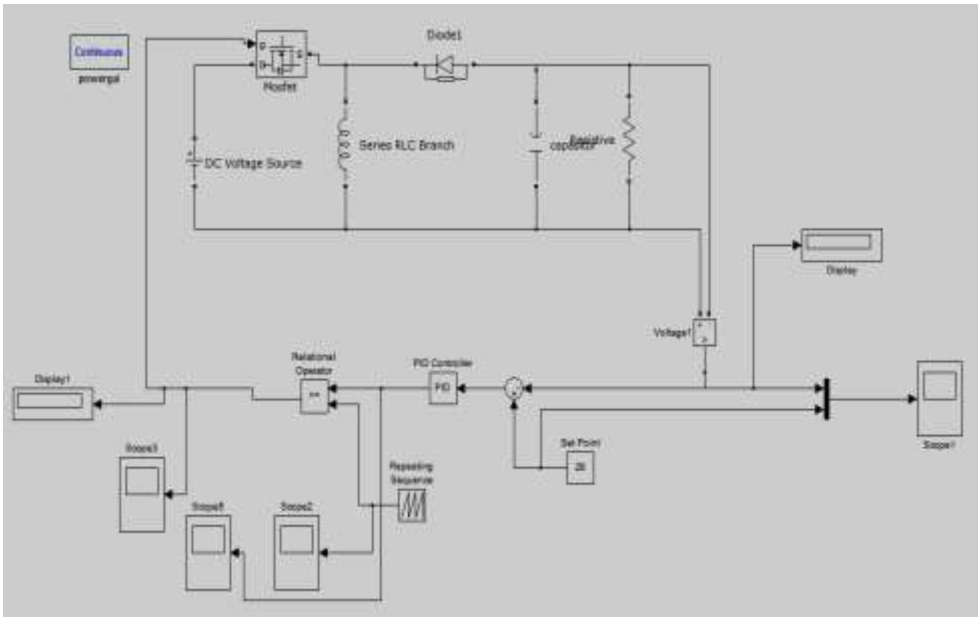
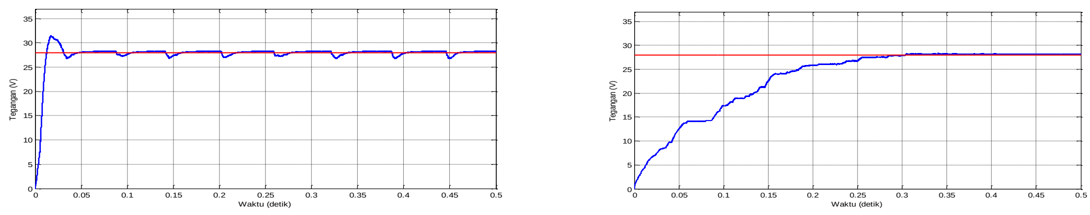


Fig. 6: Buck boost converter block diagram with PID control.

RESULTS AND DISCUSSION

3.1. Testing of Buck Boost Response with 28 V Set Point, with 10 V input, with PID and PI controls;

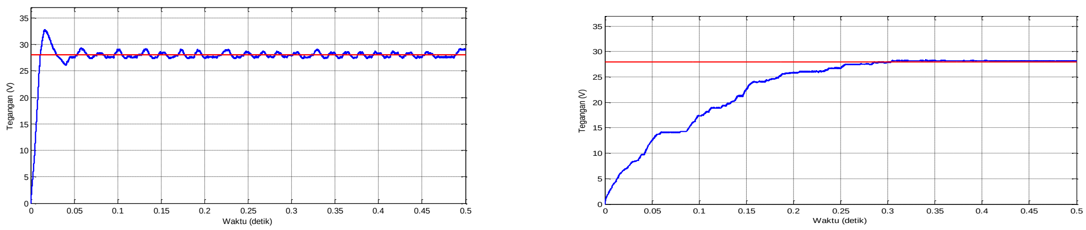


(a) **(b)**

Fig. 7: System response (a) PID controller and (b) PI control

In Figure 7 (a) it is shown that the system response is stable and can reach a set value of 28 V, with maximum overshoot (Mp) = 3.5 V, settling time (Ts) = 0.08 seconds, peak time (Tp) = 0.02 sec, rise time (Tr) = 0.01 sec and steady state error (Ess) = 0.4 V. In Figure 7 (b) it is shown that stable system response with set point 28 V obtained by maximum overshoot value Mp) = 0, settling time (Ts) = 0.33 seconds, peak time (Tp) = 0, rise time (Tr) = 0.32 sec and steady state error (Ess) = 0.12 V.

3.2. Test Response Set Point Buck Boost Converter PID and PI Mode At Input Voltage 15 V

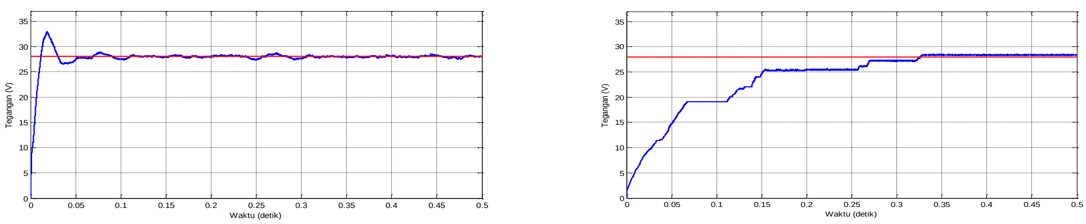


(a) **(b)**

Fig. 8: Response system with 28 V set point, Inpit voltage 15 V (a) Control PID and (b) PI.

Figure 8 (a) shows a stable system response with a set point 28 V having a maximum overshoot value (Mp) = 4.7 V, settling time (Ts) = 0.06 seconds, peak time (Tp) = 0.02 sec , Rise time (Tr) = 0.01 sec and steady state error (Ess) = 1 V. In Figure 8 (b) it is shown that the system response is stable with 28 V set point, has maximum overshoot value (Mp) = 0, settling Time (Ts) = 0.33 seconds, peak time (Tp) = 0, rise time (Tr) = 0.32 sec and error steady state (Ess) = 0.15 V.

3.4. Test Response Set Point Buck Boost Converter PID and PI Mode At Input Voltage 20 V.

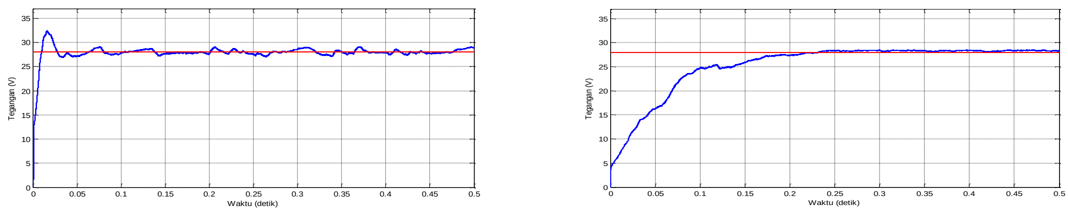


(a) **(b)**

Fig. 9: Response system with 28 V set point, input voltage 20 V, (a) PID control and (b) PI.

Figure 9 (a) shows a stable system response with a set point 28 V having a maximum overshoot (Mp) = 5 V, settling time (Ts) = 0.1 second, peak time (Tp) = 0.02 sec, Rise time (Tr) = 0.01 sec and steady state error (Ess) = 0.5 V. In Figure 9 (b) it is shown that stable system response with 28 V set point has maximum overshoot value (Mp) = 0, settling Time (Ts) = 0.35 seconds, peak time (Tp) = 0, rise time (Tr) = 0.34 sec and steady state error (Ess) = 0.3 V.

3.1. 3.5. Test Response Set Point Buck Boost Converter PID and PI Mode At Input Voltage 25 V.Uji Respon *Set Point Buck Boost Converter* Mode PID dan PI Pada Tegangan Masukan ***25 V.***

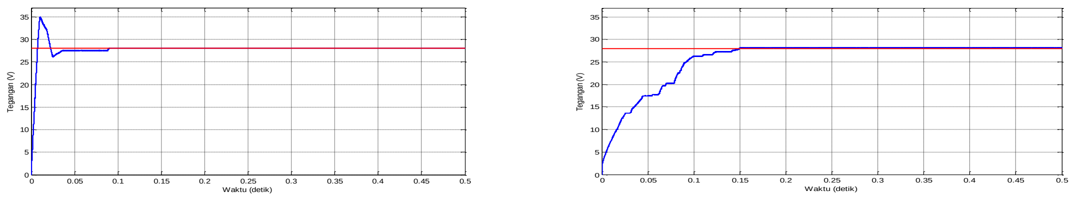


(a) **(b)**

Fig. 10: Response system with 28 V set point, 25 V input voltage (a) PID control and (b) PI.

Figure 10 (a) shows that the system response is stable with a set of 28 V, the maximum overshoot value (Mp) = 4.2 V, settling time (Ts) = 0.1 seconds, peak time (Tp) = 0.02 sec , Time rise (Tr) = 0.01 sec and steady state error (Ess) = 1 V. In Figure 10 (b) it is shown that stable system response can be achieved with 28 V set point, maximum overshoot value (Mp) = 0, Settling time (Ts) = 0.25 seconds, peak time (Tp) = 0, rise time (Tr) = 0.24 sec and steady state error (Ess) = 0.4 V.

3.2. Test Response Set Point Buck Boost Converter PID and PI Mode At Input Voltage 30 V

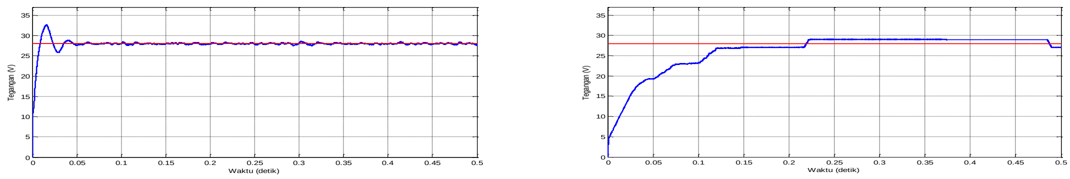


(a) **(b)**

Fig. 11: Response system with set point 28 V, input voltage 30 V (a) Control PID and (b) PI.

Figure 11 (a) shows that the system response is stable with a set of 28 V with a maximum overshoot (Mp) of 7 V, settling time (Ts) = 0.09 seconds, peak time (Tp) = 0.017 seconds, rise time (Tr) = 0.01 sec and steady state error (Ess) = 0.1 V. Figure 11 (b) shows that the system response is stable with 28 V set point, maximum overshoot value (Mp) = 0, settling time (Ts) = 0.16 seconds, peak time (Tp) = 0, rise time (Tr) = 0.15 sec and steady state error (Ess) = 0.15 V.

3.3. Test Point Buck Boost Converter Response Mode PID and PI At Input Voltage 35 V

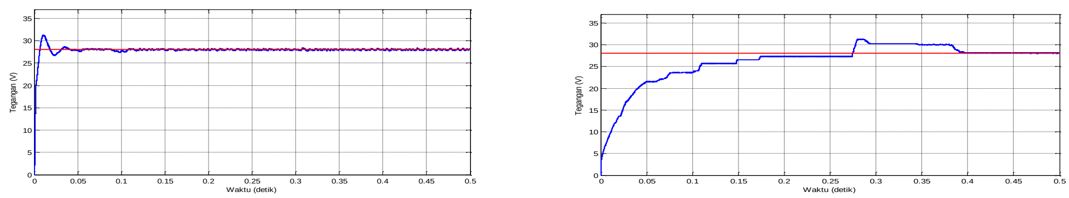


(a) **(b)**

Fig. 12: Response system with 28 V set point, input voltage 35 V (a) Control PID and (b) PI.

Figure 12 (a) shows a stable system response with a set of 28 V with a maximum overshoot (Mp) = 4.8 V, settling time (Ts) = 0.06 seconds, peak time (Tp) = 0.018 seconds, rise Time (Tr) = 0.01 sec and steady state error (Ess) = 0.4 V. Figure 12 (b) shows that the system response is stable with a 28 V set point, has a maximum overshoot (Mp) = 1 V, Settling time (Ts) = 0.48 seconds, peak time (Tp) = 0.25 seconds, rise time (Tr) = 0.21 sec and steady state error (Ess) = 1 V.

3.4. Test Response Set Point Buck Boost Converter PID and PI Mode At Input Voltage 40 V



(a) **(b)**

Fig. 13: The system response with a set of 28 V, an input voltage of 40 V (a) Control PID and (b) PI.

The Figure 13 is shown that the response of the tabil with the set point 28 V has the maximum overshoot value (Mp) = 3.2 V, settling time (Ts) = 0.08 seconds, peak time (Tp) = 0.01 seconds, rise time (Tr) = 0.008 sec and steady state error (Ess) = 0.4 V. In Figure 13 (b) it is shown that the stable system response with the 28 V set point has the maximum overshoot value (Mp) = 3 V, settling time (Ts) = 0.4 seconds, peak time (Tp) = 0.29 seconds, rise time (Tr) = 0.28 sec and steady state error (Ess) = 0.2 V.

Discussion:

From Figure 7-13 the performance of PID and PI control systems as a whole can be recap and shown by Table 5. As follows:

Tabel 5. Kinerja Sistem Buck Boost Converter dengan Mode Kontrol-PID & PI.

Table 5: Performance of Buck Boost Converter System with Control Mode-PID & PI.

Tegangan input (V)	*Max.Overshoot (%)*	Setling Time (s)	*Peak Time (s)*	*Rise Time (s)*	*Error Steady State (%)*
10-PID	0,40	0,40		0,12	0,12
10-PI	0,40				0,12
15-PID	1,00				0,15
15PI	1,00				0,15
20-PID	0,50				0,30
20-PI	0,50				0,30
25-PID	1,00				0,40
25-PI	1,00				0,40
30-PID	0,10				0,15
30-PI	0,01				0,15
35-PID	0,40				1,00
35-PI	0,40				1,00
40-PID	0,40				0,20
40-PI	0,40				0,20

In the application of PID control with set 28V point, then the best steady state error value at input voltage 30 V with value = 0,1 V. (or 1,1%). The value has been in accordance with the calculation in the design. As for the PI control system with a 20 V setpoint, the best steady-state error value is obtained at 10 V input voltage with ess value = 0.12 V or (= 1.2%). The value has already fulfilled the integrity of the built design. When compared to steady state error values of both control modes, the PID control mode has ess smaller than the PI control mode due to the difference in steady state error = 0.1%.

Conclusion:

Design of buck boost converter system with PI and PID control, it can be concluded that buck boost converter system using PID tuning control ziegler nichols got kp = 0,00273, Ti = 0,00090, and Td = 0,00023. While in control PI got value Kp = 0,002050 and Ti = 0,001494. The performance of a PI control system with a set of 28 V, and input = 10 V, has the best stability with maximum overshoot (Mp) = 0, settling time (Ts) = 0.33 seconds, peak time (Tp) = 0, rise time (Tr) = 0.32 sec and steady state error (Ess) = 0.12 V. PID control system performance with 28 V set and 30 V input has the best stability performance with maximum overshoot (Mp) = 7 V, settling time (Ts) = 0.09 seconds, peak time (Tp) = 0.017 seconds, rise time (Tr) = 0.01 sec and steady state error (Ess) = 0.1 V.

ACKNOWLEDGEMENT

The authors would like to thank the Institute for Research and Community Service (LPPM ITS), Institut Technologi Sepuluh Nopember, Surabaya. With supporting financing the research. Also, the authors would like to thank the anonymous referees for their comments on the eelier version of this work.

REFERENCES

Ali Musyafa, Ronny Dwi Noriyati, 2012. "Design Optimal in Electrical Power-Permanent Magnet Synchronous Generator of Small Scale Wind Turbine using Fuzzy Logic Control", Journal of Applied Sciences Research, 8(7): 3260-3268.

Ali Musyafa', A. Harika, I.M.Y. Negara, Imam Robndi, 2010. "Pitch Angle Control of Variable Low Rated Speed Wind Turbine Using Fuzzy Logic Control" International Journal Of Engineering & Technology IJET-IJENS 10(05): 21-24.

Ali Musyafa, A., I.M.Y. Negara, Imam Robndi, 2010. " Design Optimal in Pitch Controlled Variable speed under rated wind speed WECS Using Fuzzy Logic Control" Australian Journal Of Basic and Applied Science (AJBAS) pp: 781-788.

Australian Journal of Basic and Applied Sciences, 11(11) August 2017, Pages: 79-87

Ali Musyafa', I.M.Y. Negara, Imam Robndi, 2010. "A wind Turbine for low rated wind speed region in East Java" (IJAR, Azerbaijan), pp: 353-358.

Ali Musyafa', I.M.Y. Negara, Imam Robndi, 2011." Design Optimal of Adaptive Control and Fuzzy Logic Control on Torque-Shaft Small Scale Wind Turbine" ,Canadian Journal on Electrical and Electronics Engineering, CJEEE 2(6): 202-208.

Kalirasu dan A., S.S. Dash, 2011. *Modeling and Simulation of Closed Loop Controlled Buck Converter for Solar Installation* ., Sathyabama university, Chennai, India : International Journal of Computer and Electrical Engineering, 3.

Arifuz Z Ahmad, 2011. "Rancang Bangun Penyearah Satu Fasa Menggunakan Double Series Buck-Boost Converter Untuk Perbaikan Faktor Daya," Elektro Industri, PENS.

Badr, Munaf, 2016. *Employing Open Loop Control Model of DC-DC Buck Converter to Supply a Solenoid Coil* . F. 9, s.l. : International Journal of Engineering and Applied Sciences, 3. ISSN.

Choudhary, Dhananjay dan Saxena, Anmol Ratna, 2012. *" DC-DC Buck-Converter for MPPT of PV System.*. 7,Dept. of Electrical Engineering, Madhav Institute of Technology & Science, Gwalior, India.

Hidayat Mochamad, Suryo, 2010. "Rancang Bangun Buck Boost Konverter," Universitas Indonesia.

Kamala, J., 2010. "Enabled Smart Control Architectures and Their Application to Dc-Dc Converter," University Chennai.

Myrzik, J.M.A. and M. Calais, Member, 2003. "String and module integrated inverters for single phase grid connected photovoltaic systems – A review", Paper accepted for presentation at IEEE Bologna PowerTech Conference, June 23-26, Bologna, Italy

Kazimierczuk, Marian, 2008. "Pulse-width Modulated DC-DC Power Converters," Wright state University Dayton, Ohio, USA.

Manias Stefanos, 2000. "Power Electronics", Professorof National University of Athens, Simeon press-Coryright

Mahesh Gowda, M., N. Kiran, Yadu dan Parthasarthy, 2014. "*Modelling of Buck DC-DC Converter Using Simulink".*, Department of Electronics & Communication, PES College of Engineering, Mandya, Karnataka, India : International Journal of Innovative Research in Science, Engineering and Technology, 3.

Mohan, et al., 2013. *Power Electronics: Converters, Applications, and Design.* s.l. : John Wiley & Son.

Muhammad H. Rashid, 2001. "Power Electronics Handbook," Ph.D., Fellow IEE, Fellow IEEE, Academic press, Copyright.

Mohan, Undeland, Robbins, 1995. "Power Electronics" 2ndedtion, A.Tziolas A.E.

Patil, Bhagyashri U. dan Jagtap, S.R. 2016. " *Design of Fuzzy Based Controlling System for Buck Converter"*, Department of Electronics and Telecommunication, Rajarambapu Institute of Technology, Islampur, Sangli Shivaji University, Kolhapur. Maharashtra, India. : International Journal of Advanced Research in Computer Engineering & Technology, 4.

Hansen, L.H. et al., 2001. " Conceptual survey of generators and power electronics for wind turbines", Riso National Laboratory, Roskilde, Denmark, December.

Sulaiman R. Diary, 2010. "Desaign of High Efficiency DC-DC Converter for Photovoltaic Solar Home Application," University of Salahaddin-Hawler.

Skvarenina, Timothy L., 2002. "The Power Electronics Handbook Industrial Electronics Series," Indiana : Crc press.