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Design and Implementation of a Novel Hybrid Posicast Based Controller for a Buck-Boost Converter

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Abstract: Implementation of hybrid posicast-based control of buck-boost converter have been presented. Posicast is a feed-forward compensator to eliminate the overshoot in system behavior. Traditionally it is used as a feed-forward compensator which is sensitive to changes in natural frequency. Hence to avoid this in the conventional method, the posicast element is used within the feedback loop. Also conventionally the posicast technique is used for buck converter and boost converter. The proposed method uses the implementation of posicast technique to buck-boost converter. The posicast element is intended for the dc-dc buck-boost converter to overcome the sensitivity issue. Further the presence of RHP zeroes and other elements in the dc-dc buck-boost converter introduce undesirable effects on system stability. The posicast technique eliminates the sensitivity issue, overshoot problem and ensures steady state stability. The performance of posicast based control of buck-boost converter is compared with the ideal dynamics of the plant system and with the PID controller by simulation using MATLAB. Also the simulation result of posicast compensated system was compared with the experimental results.

Key words: Buck-boost converter · Dc-Dc converter · Feed-forward · Ideal dynamics · Overshoot · Posicast

INTRODUCTION

One of the most significant area in power electronic converters for example DC/AC converter (inverter), AC/DC converter (rectifier) and DC/DC converter (chopper), which are used in numerous applications. Among these converters, dc-dc converters have more essential features like charging or discharging of batteries, DC-link voltage adjustments between rectifier and inverter and etc [1, 3].

A buck-boost converter is a dc-dc converter (step up/step down) which has the output voltage either greater than or smaller than the input voltage.

The output of the dc-dc converter is nonlinear and has lightly damped dynamics due to the presence of RHP is zero and load parameters which results in stabilization of the systems will be complex a manner [4]. To overcome this problem novel posicast principle is used.

In general, Feed-forward and feed-back control method is used for half-cycle posicast controller especially in lightly damped systems. Half-cycle posicast (also called as classical posicast) is used to drive second-order system [5].

Classical Half-Cycle Posicast feed-back control system is used to solve resonance damping problem of LC filter in Voltage Source Inverter (VSI) [6].

The main drawback of Classical Half-Cycle Posicast control technique is sensitiveness. To overcome this problem, posicast control techniques have been proposed.

Recently invented technique of Posicast control is an effectual method of control scheme which has been used effectively in many applications. For example DSP based digital controller of the boost converters [7], Micro controller based digital control of the buck converters [8], Dynamic Voltage Restorer (DVR) [9], terminal voltage

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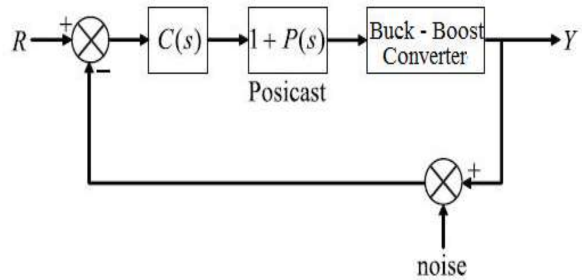

Fig. 3: Hybrid posicast feedback control

control of the generator [10], resounding of z-source current-type inverter, vibration reduction of lightly damped oscillatory systems, DSP based fuzzy controller for series parallel resonant converter [11], power system stability control [12] and so on.

Hybrid Posicast Controller (HPC) is utilized todecrease undesirable sensitivity of system. HPC is realized in DC-DC Boost Converter [13]. In this, Boost Converter is activated in Continuous Conduction Mode (CCM). HPC is also employed in DC-DC Buck Converter [14] and Single Ended Primary Inductor Converter (SEPIC) which is used in renewable energy applications [15].

Electronic realization of Posicast control system is used to decrease the vibration in Op-Amps which is mentioned in [16]. In this CMOS pre-shaper circuit is used to convert the input step pulse into a required Posicast pulse.

Adaptive posicast controller systems [17, 18] are used intime-delay systems which are used to decrease oscillations much quicker than the phase shift controller.

Apart from these, this paper, proposes a new posicast feed-back control system within the hybrid buck boost converter which is based on the Posicast principle. The proposed dc to dc buck boost converter establishedon posicast feedback control is more efficient control technique which has many advantages such as good damping of resonant behaviour, less high-frequency noise, good transient state and steadystate performances, easily determination of controller gain parameters and elimination of multiple sets of controller gains.

Proposed Hybrid Buck Boost Posicast Feedback Control: The proposed control technique for the buck-boost dc-dc converter explains the posicast within the feedback loop which is used to reduce the sensitivity. This method uses posicast element and a compensator C(S). The structure of the proposed control technique is shown in Fig. 3.

Classical posicast [19] is designed to remove the undamped oscillations of the dc-dc converter (buck-boost converter). Yet at the same time, there will be a problem due to the sensitivity. By developing posicast within the feedback loop, the sensitivity issue is reduced. The modeling of buck-boost converter, analysis and design of posicast control is explained in the section 3, section 4 and section 5. Simulation study of uncompensated system and posicast compensated system is done in section 6. Section 8 shows the comparison of PID control technique with the new control of buck-boost dc-dc converter. Simulation results are verified with the experimental result which is explained in section 9.

Modelling of Buck-Boost Converter: The dc-dc buck-boost converter (step down and step up converter) is obtained by cascadingboost (step up) and buck (step down) converter and its output voltage can be smaller than or greater than the input voltage [20]. The dynamics of dc-dc buck-boost converter can be obtained from the insignificant signal transmission function of the buck-boost converter utilizing state space averaging methods. Upon applying averaging, perturbation and linearization of inductor voltages, capacitor currents we get,

$$L\frac{d\hat{i}(t)}{dt} = D\hat{v}_g(t) + D'\hat{v}(t) + (V_g - V)\hat{d}(t) \tag{1}$$

$$C\frac{d\hat{v}(t)}{dt} = D'(t) - \frac{\hat{v}(t)}{R} + I\hat{d}(t) \tag{2}$$

$$\hat{i}_g(t) = D\hat{i}(t) + I\hat{d}(t) \tag{3}$$

The converter comprises two independent ac inputs: they are the line input □g(s) and the control input d(s). The ac output voltage variations □(s) cloud be stated as the superposition of expressionsget from these two inputs:

$$\hat{v}(s) = G_{vd}(s)\hat{d}(s) + G_{vg}(s)\hat{v}_g(s) \tag{4}$$

Hence, the transfer functions $G_{vd}(S)$ and $G_{vg}(S)$ can be defined as

$$G_{vd}(s) = \left.\frac{\hat{v}(s)}{\hat{d}(s)}\right|_{\hat{v}_g(s)=0} \text{ and } G_{vg}(s) = \left.\frac{\hat{v}(s)}{\hat{v}_g(s)}\right|_{\hat{d}(s)=0} \tag{5}$$

Taking the Laplace transform of the above equations

$$sL\hat{i}(s) = D\hat{v}_g(s) + D'\hat{v}(s) + (V_g - V)\hat{d}(s) \tag{6}$$

$$sC\hat{v}(s) = -D'\hat{i}(s) - \frac{\hat{v}(s)}{R} + I\hat{d}(s) \tag{7}$$

And by Simplifying

$$\hat{v}(s) = \left(-\frac{D}{D'}\right)\frac{1}{1+s\frac{L}{D'^2R}+s^2\frac{LC}{D'^2}}\hat{v}_g(s) - \left(\frac{V_g-V}{D'}\right)\frac{\left(1-s\frac{LI}{D'(V_g-V)}\right)}{1+s\frac{L}{D'^2R}+s^2\frac{LC}{D'^2}}\hat{d}(s) \tag{8}$$

The line to output transfer function is

$$G_{vg}(s) = \left.\frac{\hat{v}(s)}{\hat{v}_g(s)}\right|_{\hat{d}(s)=0} = \left(-\frac{D}{D'}\right)\frac{1}{1+s\frac{L}{D'^2R}+s^2\frac{LC}{D'^2}} \tag{9}$$

The mechanism to output transfer function is

$$G_{vd}(s) = \left.\frac{\hat{v}(s)}{\hat{d}(s)}\right|_{\hat{v}_g(s)=0} - \left(\frac{V_g-V}{D'}\right)\frac{\left(1-s\frac{LI}{D'(V_g-V)}\right)}{1+s\frac{L}{D'^2R}+s^2\frac{LC}{D'^2}} \tag{10}$$

where:

Vg - Input voltage
V - Output voltage
L - Filter inductance
C - Filter capacitance
R - Load resistance
D - Duty cycle
D' - (1-D)

Using the plant parameters of the system shown in Table 1,

$$G_{vd}(s) = \frac{-190 + 1.1\times10^{-2}s}{1 + 1.0\times10^{-4}s + 1.6\times10^{-7}s^2} \tag{11}$$

The step response of uncompensated buck-boost converter is presented in Fig. 4. It illustrate that the system is oscillatory and is overcome by posicast technique.

Implementation of Posicast Control: The posicast control technique is adopted in lightly damped systems to overcome the oscillations. The oscillations in dc-dc converters are produced because of its sensitivity to changes in the natural frequency [21-23]. The proposed method uses the implementation of posicast control to buck-boost converter. The analysis for the proposed approach is obtained from the small signal transfer of buck-boost converter by determining the values of

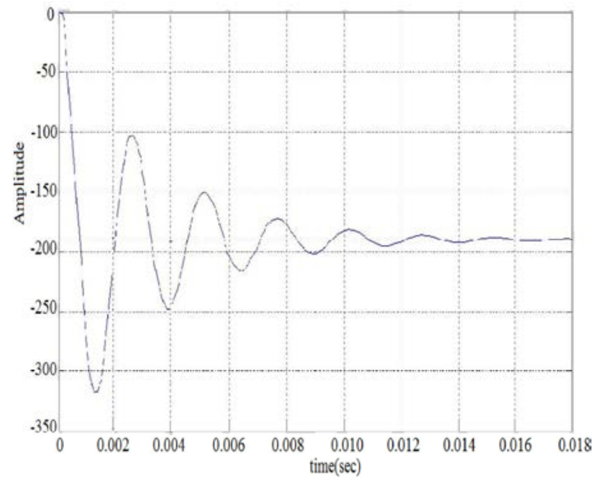

Fig. 4: Step response of uncompensated buck-boost converter

Table 1: Plant Parameters

Parameters	Symbol	Values
Input voltage	V_g	25-35v
Load current	I	1.9A
Switching frequency	f_s	25khz
Inductor	L	160 µH
Capacitor	C	160 µF
Load resistor	R	10Ω
Duty cycle	D	0.6

the restrained time period 'Td' and the step overshoot 'δ'. Using this, the posicast function is obtained. The new way of implementing the posicast control to buck-boost converter reduces the overshoot and also reduces the sensitive issue compared with the other control techniques which have been discussed in the section 2.4 and in section 4.

Design of Posicast Controller: The design of posicast control is obtained based on the ideal dynamics of the buck-boost dc-dc converter given in eqn (12), This equation is of the form

$$G_{vg}(s) = G_{g0}\frac{1}{1+\frac{s}{Q\omega_0}+\left(\frac{s}{w_0}\right)^2} \tag{12}$$

By comparing both the equations we have,

$$V = -\frac{DV_g}{D'} \tag{13}$$

$$I = -\frac{V}{D'R} \tag{14}$$

Also by associating with the typical equation of the standard second order method, we get the damping factor as 'ζ 'and undamped natural frequency '$\Omega 0$'.

$$\omega_0 = \frac{D'}{\sqrt{LC}} \tag{15}$$

$$\zeta = \frac{1}{2RD'}\sqrt{L/C} \tag{16}$$

With this, the damped time period 'Td' and the stage overshoot 'δ' are obtained since the standard time domain specifications

$$T_d = \frac{2\pi}{\omega_n\sqrt{1-\zeta^2}} \tag{17}$$

$$\delta = e^{-\zeta\pi/\sqrt{1-\zeta^2}} \tag{18}$$

A half cycle posicast transmission function is given as 1+P(s) where P(s) is defined as

$$P(s) = \frac{\delta}{1+\delta}\left(e^{-s(T_d/2)} - 1\right) \tag{19}$$

This is intended for the buck-boost converter. To take the benefit of posicast and considering the load sensitivity, the posicast is used within the feedback. To reduce the stable state instabilities, a compensator of integrator sort is employed

$$C(S) = K/s \tag{20}$$

The combined hybrid control transfer function is given by

$$C(s)\left(1+P(s)\right) = \frac{K}{s}\left[1 + \frac{\delta}{1+\delta}\left(e^{-s(T_d/2)} - 1\right)\right] \tag{21}$$

$$C(s)\left(1+p(s)\right)G_p(S) = \frac{-4.6e^{3} + 2.6e^{-1}s - 3e^{3}e^{-s1.3e-3} + 1.8e^{-1}se^{-s1.3e-3}}{s + 1.0e^{-4}s^2 + 1.6e^{-7}s^3} \tag{22}$$

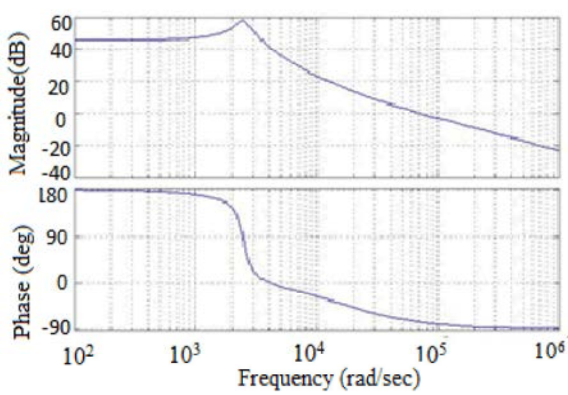

Fig. 5: Frequency response of the uncompensated buck – boost converter

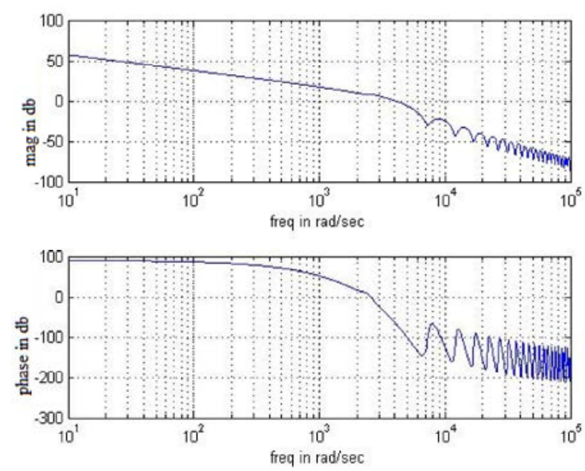

Fig. 6: Frequency response of the posicast compensated Buck –Boost Converter

The frequency reaction of the posicast-compensated open- loop function c(s) [1+P(s)] Gp(s) is mentioned in Figure 6 and for the uncompensated system is presented in Figure 5.

Comments on Posicast Control: The frequency reaction [24, 25] of uncompensated open loop transmission function shows that the structure suffers due to overshoot. Also the phase margin of the uncompensated system shows that the system is unstable which is mentioned in Fig 5. But the frequency response of posicast controlled compensated system shown in Fig 6, illustrates that the overshoot has been completely eliminated. Thus the posicast compensated system has no overshoot. Also the phase margin is 110 degree, which ensures the system is stable.

Simulation Details and Results: The simulation model of hybrid posicast compensated DC-DC buck boost converter have been explained by the following MATLAB Simulink model for the input voltage of 30V, duty cycle 0.6, output voltage of 45V and R = 10Ω.

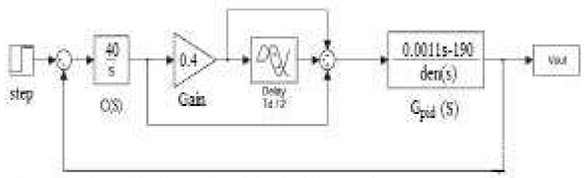

Fig. 7: Simulink typical hybrid Buck –Boost converter

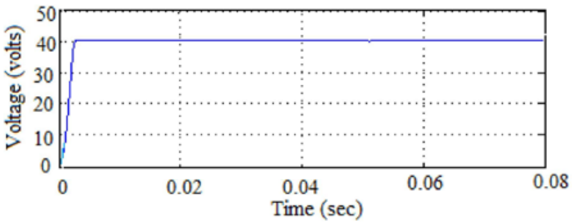

Fig. 8: Output voltage for an input voltage of30V

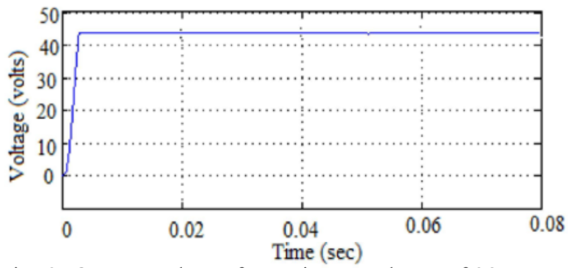

Fig. 9: Output voltage for an input voltage of 32V

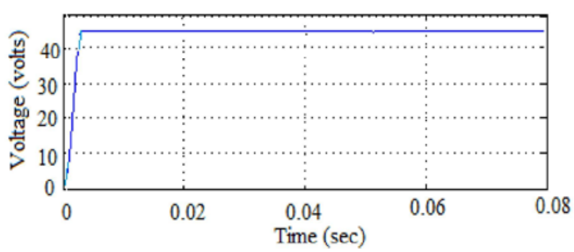

Fig. 10: Output voltage for an input voltage of35V

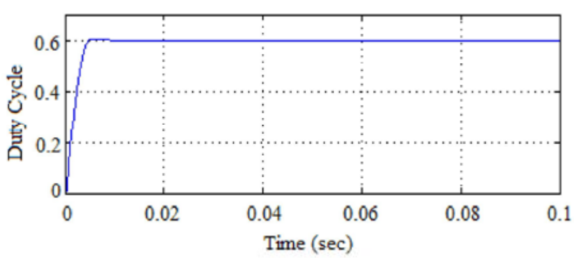

Fig. 11: Simulated Duty Cycle

The simulated duty cycle and output voltage is given in Figure 8. For a given input voltage of the 30V, the output voltage is 40V.

It is found that even the input voltage is varied the Thus the implementation of posicast control to buck-boost converter provides an effective output voltage regulation irrespective of parameter variations. Thus the posicast control is insensitive to parameter variations.

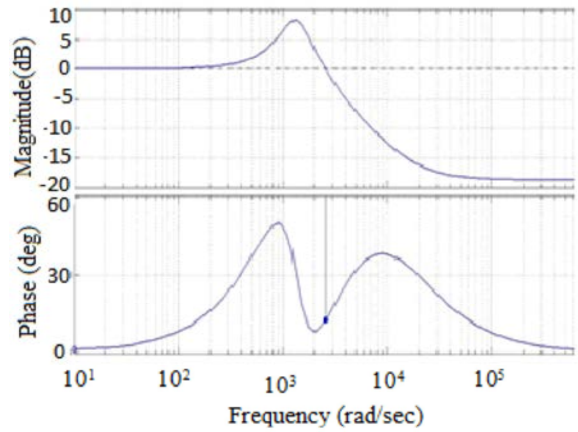

Fig. 12: Frequency response of PID compensatedmethod

The simulated output voltage for various input voltages are given in Fig. 9, Fig. 10. The output remains constant for various input voltages. This ensures that posicast compensated system provides good regulation, irrespective of the problems due to parameter and load variations.

Fig. 11 shows the variation of duty cycle with respect to time by matlab simulation. It shows that the duty cycle is 0.6 and beyond that, it is constant. Thus for an output voltage of 35V and input voltage of 30 V, duty cycle is 0.6.

Comparsion of PID Converter: The proposed control technique is associated with the classical PID control method. The transfer function of the conventional PID controller for the plant transfer function is designed by using Zeigler-Nichols tuning method and is given by.

$$G_{pid}(s) = 5.45e-3\left(1+\frac{1}{1.47e-3s}+3.675e-4s\right) \quad (23)$$

The bode plot of the PID controller for the buck-boost converter is as below,

As the plant transfer function of dc-dc buck-boost converter transfer function has integrator term, the design of PID controller is difficult. Hence, the open loop frequency response has maximum overshoot. The frequency response of PID controller for buck-boost converter shown in Fig. 12 illustrates that it has more overshoot and results in an unstable system. Hence to get rid of overshoot problem, the conventional control method of using PID control is overcome by using posicast control. Also the PID controller has the problem of tuning three control parameters, which is difficult and tedious. But the proposed control method has no such problem of tuning and the frequency response has no overshoot.

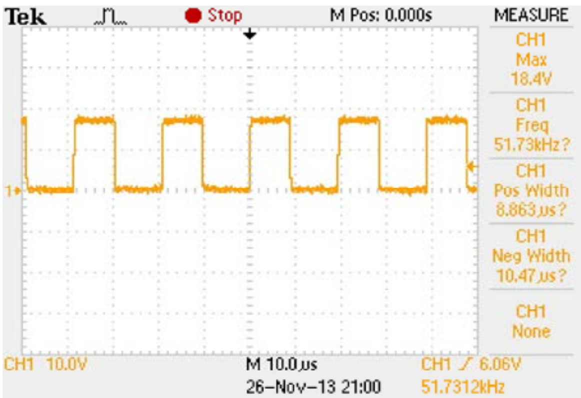

Fig. 13: Input Pulse pattern of hybrid controller

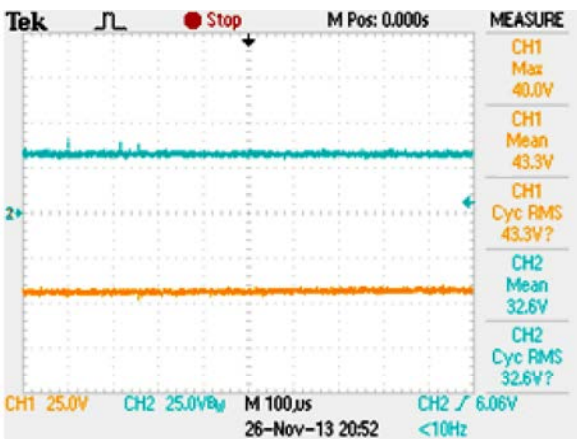

Fig. 14: Input and Output voltage of buck-boost Converter with posicast controller

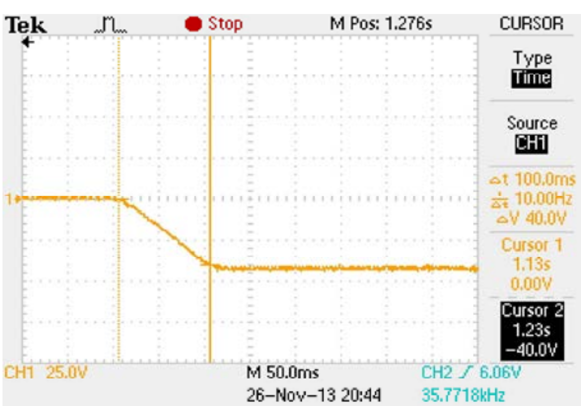

Fig. 15: Steady state output voltage

Experimental Results: The novel hybrid posicast control for buck boost converter has been tested experimentally. The parameter values have been listed in Table 1. The input pulse pattern of the hybrid controller is shown in Fig. 13.

Table 2: Converter output voltage for various input voltages

Input Voltage (V)	Output Voltage (V)	Deviation (mV)
28	39.988	12
29	39.990	10
30	39.992	08
31	39.993	07
32	39.995	05
33	39.998	02
34	40.002	02
35	40.005	05

Table 3: Comparison between Simulated and Hardware output voltages for various input voltages

Input Voltage (V)	Simulated Output Voltage(V)	Hardware Output Voltage(V)
30	40	39.992
32	43	39.995
35	45	40.005

With the parameter values listed in Table.1, the posicast control of buck-boost converter has been constructed. The input voltage and output voltage waveforms are illustrated in Fig.14

The steady state converter output voltage with posicast controller has been shown as below.

The posicast controller has been tested for various input voltages and their corresponding input voltage is as follows.With the Vref =40V, K=40, δ=0.4, Td /2=1.3ms, R=10Ω, the converter output voltage for different input voltages is listed in Table 2.

CONCLUSION

The novel posicast based control for dc-dc buck-boost converter has been presented. This hybrid method employs the posicast within the feedback structure to damp out the oscillations, while dropping the sensitivity of half cycle classical posicast and the response has no overshoot. Though the proposed analysis of posicast control for the buck-boost converter is quite complex, compared to buck converter and boost converter, it yields satisfied result of greatly reducing the sensitivity and overcomes the overshoot. Also the use of integral controller ensures steady state response. The proposed technique eliminates the difficulty of tuning three parameters as in the case if PID controller. Hence the posicast based control is seems to be an effective technique for output voltage regulation using buck- boost converter.

REFERENCES

1. Dibya Bharti, Pankaj Rai and Ramjee Prasad Gupta, 2012. Modelling and Simulation of Buck Boost DC-DC Converter with High Stability for Low Power Application, in proc. VSRD-IJEECE, 2(9): 679-686.
2. Zaur Tariguliyev and Berna Ors, 2013. Reliability and security of arbiter-based physical unclonable function circuits, International Journal of Communication Systems, 26(6): 757-769.
3. Omar M. Hasan and Ahmad Hiasat, 2004. Limiter discriminator detection of narrow-band duobinary FSK in a land mobile channel, International Journal of Communication Systems, 17(1): 85-97.
4. Bhavesh Dave, XXXX. Design & Simulation of Buck-Boost converter Modulation Technique for Solar Application, in proc.of Journal of Information, Knowledge and Research in Electrical Engineering, Issn: 0975 – 6736, volume – 02, issue – 02, Nov 12 to Oct 13.
5. John Y. Hung, 2007. Posicast Control Past and Present," in proc. of IEEE Multidisciplinary Engineering Education Magazine, 2(1).
6. Zachary T. Dydek, Anuradha M. Annaswamy, Jean-Jacques E. Slotine and Eugene Lavretsky, 2013. Composite adaptive posicast control for a class of LTI plants with known delay, in proc. Elsevier, Automatica, 49(6): 1914-1924.
7. Feng, Q., J.Y. Hung and R.M. Nelms, 2003. Digital control of boost converter using posicast, in Proc. 18thAnnu.IEEE Appl. Power Electron. Conf. Expo., Miami, FL, pp: 99-388, Feb 9- 3, 2003.
8. Feng, Q., J.Y. Hung and R.M. Nelms, 2006. Posicast – Based Digital Control of the Buck Converter in IEEE Trans on Ind. Electron, 53(3).
9. Aghamohammadi, M.R., A. Ghorbani and S. Pourmohammad, 2008. Enhancing transient and small signal stability in power systems using a posicast excitation controller, in proc. IEEE 48th International conf. Of Universities Power Engineering Conference, pp: 1-5.
10. Ghorbani, A., S. Pourmohammad and M.S. Ghazizadeh, 2008. Mitigation of oscillations due to changing the reference signal of the excitation system using a Posicast controller, in proc. IEEE 12th International conf. Of Power System Conference, pp: 57-61.
11. Madheswaran, M. and C. Nagarajan, 2012. DSP based fuzzy controller for series parallel resonant converter, Springer, Frontiers of Electrical and Electronic Engineering, 7(4): 438-446.
12. Allahverdi Azadrou, Amir Ghorbani and Vahid Hajiaghay, 2011. Enhancing Transient Stability in Power Systems Using a New Excitation Controller, Australian Journal of Basic and Applied Sciences, 5(7): 968-975.
13. Ramash K. Kumar and S. Jeevananthan, 2011. Design of a Hybrid Posicast Control for a DC-DC Boost Converter Operated in Continuous Conduction Mode, proc. IEEE, 2011.
14. Kaithamalai Udhayakumar, Ponnusamy Lakshmi and Kandasamy Boobal, 2008. Hybrid Posicast Controller for a DC-DC Buck Converter, proc. Serbian Journal of Electrical Engineering, 5(1): 121-138.
15. Kalantar, M. and S.M. Mousavi G., 2010. Posicast control within feedback structure for a DC–DC single ended primary inductor converter in renewable energy applications, in proc. Elsevier, Applied Energy, 87(10): 3110-3114.
16. Rasoulzadeh, M. and M.B. Ghaznavi-Ghoushchi, 2009. Design and Implementation of a CMOS Posicast Pre-Shaper for Vibration Reduction of Op-Amps, Proc. World Congress on Engineering and Computer Science 2009 (WCECS 2009), Vol I, October 2009.
17. Yildiray Yildiz, Anuradha Annaswamy, Ilya V. Kolmanovsky and Diana Yanakiev, 2010. Adaptive posicast controller for time-delay systems with relative degree n*=2," *Elsevier,* 46(2): 279-289.
18. Park, S., D. Wee, A.M. Annaswamy and A.F. Ghoniem, 2002. Adaptive low-order posicast control of a combustor test-rig model, in Proc. 41st IEEE Conference, 4: 3698-3703.
19. Hung J.Y, 2002. Application of Posicast principles in feedback control, in proc. IEEE Trans. On Industrial Electronics, 2: 500-504.
20. Guo, L., J.Y. Hung and R.M. Nelms, 2002. PID controller modifications to improve steady-state performance of digital controllers for buck and boost converters, in Proc. 17th Annu. IEEE Appl. Power Electron. Conf. Expo., Dallas, TX, pp: 381-388.
21. John Y. Hung, 2003. Feedback control with posicast, in proc. of IEEE Trans. lnd. Electron., 50(1): 94-99.

22. Hurák, Zdeněk, Martin Hromčík and Martin Špiller, 32007. Minimization of l2 norm of the error signal in posicast input command shaping: a polynomial approach, International Journal of Robust and Nonlinear Control, 17(8): 706-719.
23. Hoang-Linh To, Suk-Hwan Lee and Won-Joo Hwang, 2014. A burst loss probability model with impatient customer feature for optical burst switching networks, International Journal of Communication Systems, MAR 2014, DOI: 10.1002/dac.2772
24. Chen, H.H., 2003. Performance analysis of an improved multi-carrier CDMA system under frequency-selective Rayleigh fading channels. Int. J. Commun. Syst., 16: 627-646. doi: 10.1002/dac.610.
25. Ertan Öztürk and Barış Şahin, 2007. Performance of optimum wavelet for DS-CDMA chip waveform over multi-path Rayleigh fading channels, International Journal of Communication Systems, 20(9).