Design and Implementation of KY Buck-Boost Converter with Voltage Mode Control

G. Saritha, D.Kirubakaran

Abstract— This paper introduces a straightforward voltage mode simple controller for an improved KY buck-support converter. The improved KY buck-help converter includes a KY support converter and a synchronous buck converter. The voltage mode simple control is planned by utilizing a PI controller to direct the yield voltage of the converter. An exploratory model of KY buck-help converter of 30 Watt, 12 V yield voltage, 10 kHz with discrete simple controller is planned and created for an information voltage 10V-16V. The usefulness of the converter with the controller under shut circle is shown for the variety in info voltage.

Index Terms—buck–boost converter, KY converter, Synchronous buck converter, PI controller.

I. INTRODUCTION

By and large, batteries are utilized as a power source in compact applications and they are variable in nature. DC-DC switch mode converters are broadly being utilized in low power compact applications due to their extremely high proficiency and little size. Numerous new topologies of DC-DC converters have been investigated to fulfill the developing need in the territory of switch mode control supplies. They are help converter [1], double lift converter [2], Luo converter [3], buck converter [4], buck– support converter [5], Zeta converter [6], SEPIC [7], Cuk convert-er [8] and KY converter [9] and so forth The lift converter [1], double lift [2] converter and Luo converter [3] which supports the info voltage, have right-half plane zeros in the consistent conduction mode (CCM) that lessens the framework dependability at high frequencies. The KY support converter [10] is acquainted with beat this issue dependably works in CCM making the relating current swells little and has no RHP zero. In writing [11], an improved KY support converter is con-structed for the most part by one charge siphon capacitor and one focal tapped coupled inductor. The KY converter is joined with the synchronously redressed (SR) support converter to make another voltage-boosting converter, KY help converter [12] for low power applications. The buck converter [4] that means down the information voltage gives significant measure of yield voltage swell and con-duction misfortune. So synchronous strategy [13], [14] is utilized to lessen the conduction misfortunes and raise the effectiveness. However, at high recurrence the exchanging misfortunes increment in this manner de-wrinkle the effectiveness.

Revised Manuscript Received on June 14, 2019.

G. Saritha, Research Scholar, Sathyabama Institute of Science and Technology, Chennai. Professor, St. Joseph's Institute of Technology. Chennai, Tamil Nadu

D. Kirubakaran, Research Scholar, Sathyabama Institute of Science and Technology, Chennai. Professor, St. Joseph's Institute of Technology. Chennai, Tamil Nadu

The KY buck-help converter revealed in [15] has numerous great highlights when contrasted with other DC-DC converters for compact applications. The KY buck-help converter utilizes just two switches, which are worked in synchronous way. This diminishes the expense and size of the circuit and can work in bidi-rectional mode. The extremity of the yield voltages of buck– help [5], Zeta [6], SEPIC [7], Cuk [8], and single-switch buck– support [16] converters are inverse in extremity with info volt-age while the KY buck - help converter gives the out-put voltage of same extremity with information voltage. The KY buck-support converter does not have RHP zero that increments stabil-ity and transient reaction [17]. A straightforward voltage mode simple controller is proposed in this work for the KY buck-help con-verter to direct the yield voltage. The structure of this paper is as per the following: Section II dis-cusses the standards of activity of the KY buck-help con-verter. The usefulness of the converter with the controller is checked utilizing MATLAB/SIMULINK and the recreation re-sults are introduced in segment III. Segment IV exhibits the usefulness of the controller with test results. The finish of the paper is examined in area V.

II. KY BUCK-BOOST CONVERTER

This segment clarifies the guideline of activity of the KY buck-support converter under relentless state to acquire voltage con-adaptation proportion.

2.1 Principle of Operation

The topology of the KY buck-help converter [15] is appeared in Fig 1. This consolidates a synchronous buck converter shaped by two power switches S1, S2, capacitor C1, inductor L1 and the KY support converter framed by two power switches S1, S2, control diode D, yield inductor L2, capacitor C2 and yield capacitor Co with the normal yield load Ro, individually. The rule of activity of the converter is clarified dependent on volt-second equalization and charge parity of the inductors and capacitors over an exchanging timespan individually. It is accepted that the segments utilized in the circuits are ideal.There are chiefly two working modes, Mode I (switch S1 is ON and S2 is OFF) and Mode II (turn S1 is OFF and S2 is ON) separately. The usefulness of the circuit under two working modes is talked about underneath.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

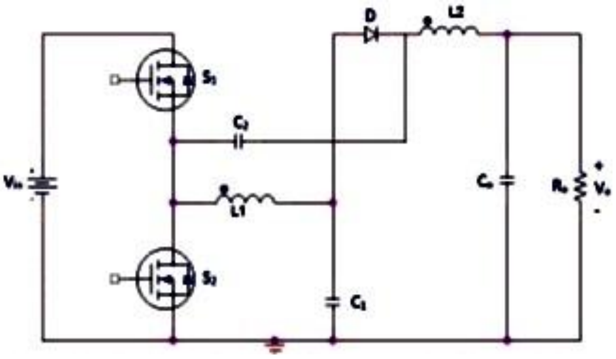

Fig 1: Circuit diagram of the KY buck-boost Converter

2.1.1 Mode I (S1 ON, S2 OFF):

In this mode the info voltage gives vitality to C1 and L1 making C1 getting charged and L1 to be polarized as appeared comparable circuit outline, Fig 2. At a similar minute, the info voltage alongside capacitor C2 supplies the vitality for inductor L2 and to the yield which causes C2 to be dis-charged and L2 getting polarized.The related conditions in Mode I are,

$$v_{L1} = V_{in} - v_{C1} \quad \text{...(1)}$$

$$v_{L2} = V_{in} + v_{C2} - V_0 \quad \text{...(2)}$$

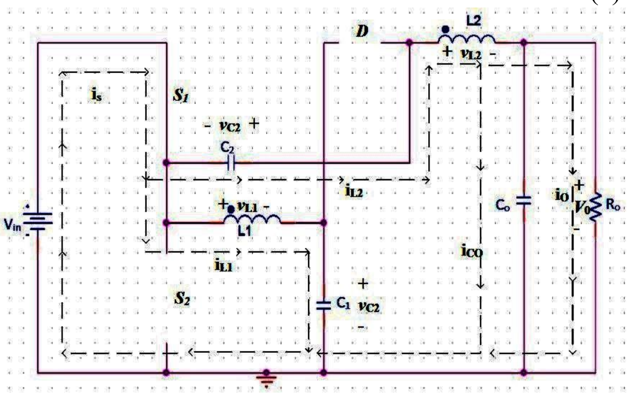

Fig 2: Equivalent Circuit Diagram under Mode I

2.1.2 Mode II (S1 OFF, S2 ON):

The proportional circuit chart amid this method of activity is appeared in Fig 3. The vitality put away in inductor L1 and capaci-tor C1 are discharged to capacitor C2 and to the yield through induc-tor L2 causing C1 to be released and L1 to be demagnetized.

At a similar minute, the voltage crosswise over L2 is vC2 less Vo, therefore making C2 to be charged and L2 being demagnetized.

The related conditions in Mode II are

$$v_{L1} = -v_{C1} \quad \text{...(3)}$$

$$v_{L2} = v_{C2} - V_0 \quad \text{...(4)}$$

$$v_{C1} = v_{C2} \quad \text{...(5)}$$

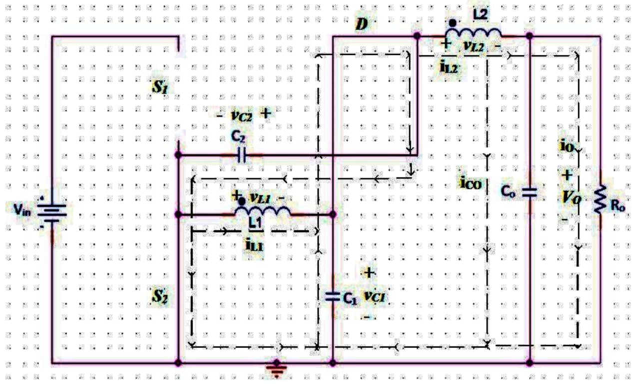

Fig 3: Equivalent Circuit Diagram under Mode II

By applying volt-sec equality for inductor L1 over a changing period from eqn (1) and (3) we get,

$$(V_{in} - v_{C1}).D.T + (-v_{C1}).(1-D).T = 0$$

$$v_{C1} = DV_{in} \quad \text{...(6)}$$

By applying volt-sec leveling for inductor L2 over a changing period from eqn (2) and (4) we get,

$$(V_{in} - v_{C2} - V_0).D.T + (v_{C2} - V_0).(1-D).T = 0 \quad \text{...(7)}$$

By setting condition (5) and (6) into (7), the last voltage change extent under predictable is gained as

$$\frac{V_0}{V_{in}} = 2D \quad \text{...(8)}$$

It might be seen that the converter can make the yield voltage not as much as data voltage (buck assignment) for commitment extent under 0.5 and produce the yield voltage more than information voltage (bolster movement) for commitment extent more imperative than 0.5.

Under suffering state the DC voltages across over capacitors C1 and C2 are comparable and given as,

$$v_{C1} = v_{C2} = 0.5V_0 \quad \text{...(9)}$$

2.2 Design Specifications of the Converter

The KY buck – help converter is structured dependent on the plan particulars, which are recorded given below

- I/P Voltage - 10V - 16V
- O/P voltage- 12V
- Load Current -2A
- Switching frequency -10kHz
- Inductor
- L1- 3000 µH
- L2 -1000 µH
- Capacitor
- C1- 470 µF
- C2 -220 µF
- Co -47 µF

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

A straightforward PI controller is intended to manage the yield voltage of the converter dependent on the accompanying plan particular.

III. DESIGN OF PI CONTROLLER

The transfer function of PI controller is

$$G_C(s) = K_p + \frac{K_i}{S} \quad \ldots(10)$$

The values of Kp = 1.389 * 10^-3 and Ki = 40 are obtainedfrom the root locus technique.

3.1 Closed Loop Operation of the Converter in MATLAB

The KY buck-help converter with the PI controller is simulat-ed in MATLAB/SIMULINK as appeared in fig 4. The yield voltage when worked in buck and lift mode in MATLAB reenactment are appeared in Fig 5 and Fig 6 individually.

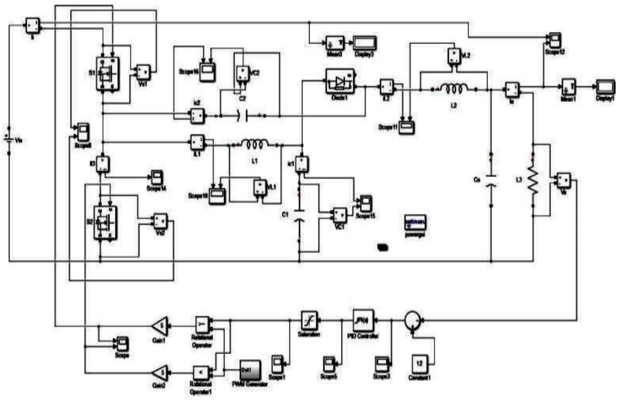

Fig 4: Closed loop converter circuit using PI controller.

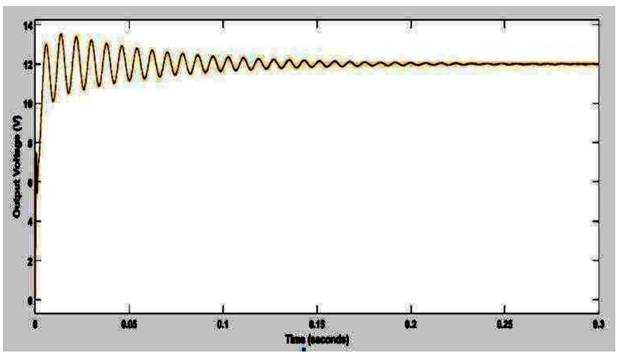

Fig 5: Output voltage in buck operation

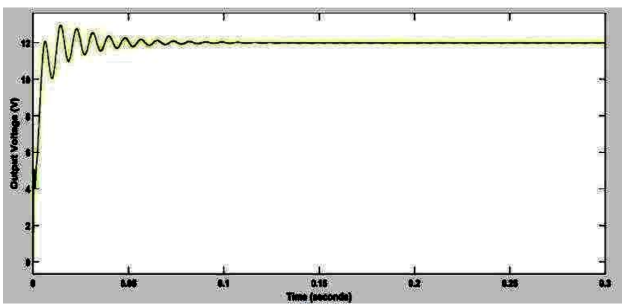

Fig 6: Output voltage in boost operation

It very well may be seen from the progression reactions of the converter that the yield voltages achieve relentless state esteem. Subsequently, it very well may be reasoned that the structure estimations of PI controller for the shut circle task are proper. The equipment setup of the converter with PI controller is exhibited in the following segment.

IV. HARDWARE IMPLEMENTATION OF THE CONVERTER WITH PI CONTROLLER

An test model of 30Watt, 12V yield voltage, 10kHz KY buck-support converter is planned and produced for an information voltage run 10V-16V. The controller is planned utilizing simple discrete parts. The rundown of all parts utilized in the power circuit and the control circuit are recorded in Table 1 and Table 2 individually.

TABLE 1

Components used in the Power Circuit

S.No.	COMPONENT	VALUE
1	MOSFET	IRF530
2	Diode	MIC6A4
3	Capacitors	470 µF, 63V – 1 no. 220 µF, 63V - 1 no. 47 µF, 63V - 1 no.
4	Inductors	3000 µH - 1 no. 1000 µH - 1 no.
5	Load Resistor	300 ohm, 5A

TABLE 2

Components used in the Control Circuit

S.No.	COMPONENT	VALUE
1	Op amp	LM741
2	Schmitt trigger inverter	74HC14
3	Transistor	BC557A
4	Zener diode	MILL750
5	Diode	1N4007
6	Not gate	74LS04
7	Driver	TLP250
8	555 timer	1 no.

4.1 Description of the Experimental set up

The complete schematic of the experimental prototype is shown in Fig 7.

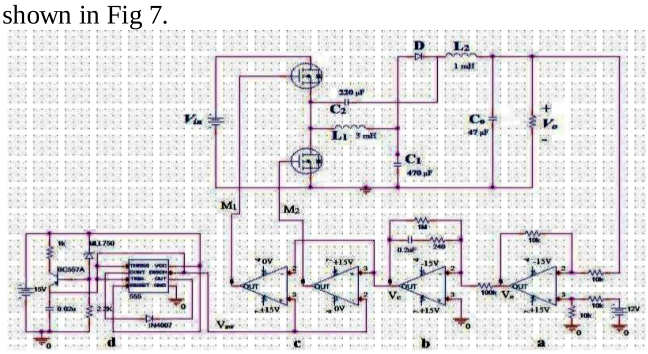

Fig 7: Schematic of the KY buck-boost converter with PI controller under closed loop.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The yield voltage Vo is contrasted and the reference voltage of 12V to get a blunder voltage (Ve) as appeared in Fig 7 section (a). At that point this mistake voltage (Ve) is given as contribution to the PI controller to gain the power voltage (Vc) as appeared in Fig 7 section (b). Presently the got control voltage (Vc) is contrasted and the saw tooth voltage (Vsw) to get the ideal exchanging beats (M1, M2) which are appeared in Fig 7 section (c). These exchanging beats are connected through a driver circuit (TLP250) to the switches S1 and S2. A 555-clock is utilized for the age of saw tooth waveform. The saw tooth voltage waveform of 10 kHz got from the circuit is appeared in Fig 8.

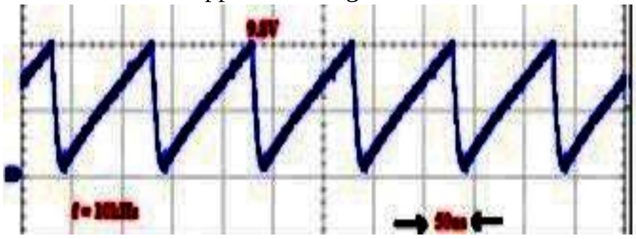

Fig 8: Saw tooth voltage from the 555 timer.

4.2 Experimental Results

4.2.1 Buck Mode of Operation:

The shut circle task of the converter in buck mode is directed with a voltage contribution of 16V for a reference voltage of 12V. The relating yield voltage, door beats for switch S1, S2 and the voltage over the switch S2 are appeared in Fig 9(a), 9(d), 9(c) and 9(b) separately. It very well may be seen that the controller creates the control motion for the switch S1 with a rough obligation proportion of 40% to deliver the yield voltage 12V.

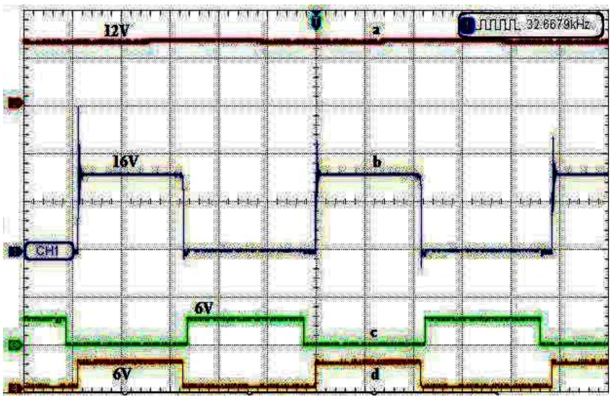

Fig 9: (a) Output Voltage, (b) voltage over switch S2, (c) M2, (d) M1.

4.2.2 Boost Mode of Operation:

The shut circle task of the converter in lift mode is led with a voltage contribution of 11V for a reference voltageof 12V. The relating yield voltage, door beats for switch S1, S2 and the voltage over the switch S2 are appeared in Fig 10(a), 10(d), 10(c) and 10(b) individually. It very well may be seen that the controller creates the control motion for the switch S1 with an inexact obligation proportion of 56% to deliver the yield voltage 12V.

The trial results showed above for the KY buck-support converter exhibit the fruitful task of the PI controller under enduring state.

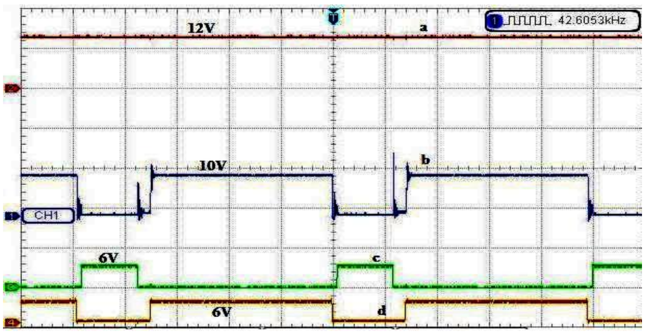

Fig 10: (a) Output Voltage, (b) voltage over switch S2, (c) M2, (d) M1

The dynamic exhibitions of the controller are available ed with step changes in information voltage. The dynamic yield voltage waveforms when the info is changed from 0-16 V and 0-11V at 1A are appeared in Fig 11 and Fig 12 separately.

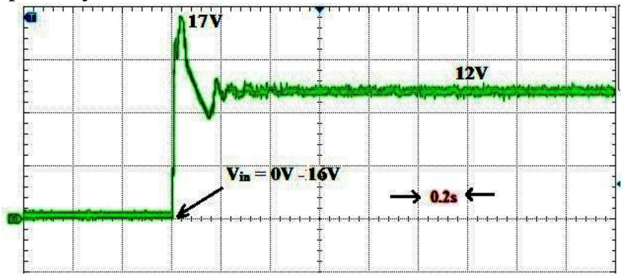

Fig 11: Output Voltage for step change in input from 0 - 16V.

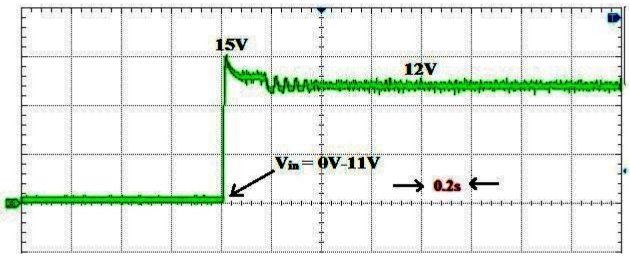

Fig 12: Output Voltage for step change in input from 0 - 11V.

The complete hardware setup of the KY buck-boost con-verter using PI controller is shown in Fig 13.

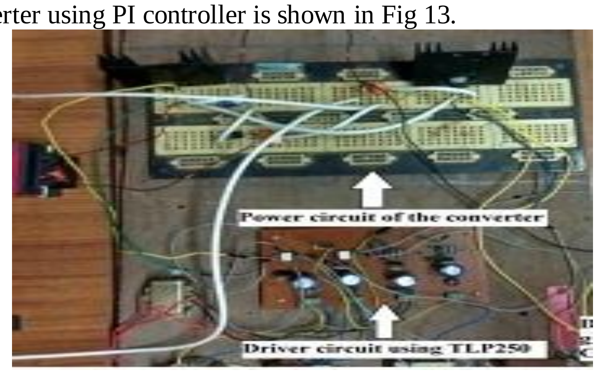

Fig 13: Hardware setup of the KY buck-boost con-verter

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

From all the above test results it tends to be con-cluded that the structure of the proposed controller for the KY buck-support converter fulfill the shut circle task under unfaltering state and dynamic conditions. The finish of the work is examined straightaway.

V. CONCLUSION

This paper presents structure and usage of the KY buck support converter. A basic PI controller is proposed and intended to direct the yield voltage of the converter. Reproduction and equipment results are displayed to check the usefulness of the converter with the controller under unfaltering state and dynamic conditions.

REFERENCES

1. Bryant, B., and Kazimierczuk, M. K., "Voltage loop of boost PWM DC-DC converters with peak current-mode control," IEEE Trans. Circ. Syst. I: Reg. Papers, Vol. 53, No. 1, pp. 99–105, 2006.
2. Sayed, A., Abdel-Salam, M., Ahmed, A., and Ahmed, M., "New high voltage gain dual-boost DC-DC converter for photovoltaic power systems," Electr. Power Compon. Syst., Vol. 40, pp. 711–728, 2012.
3. Luo, F. L., and Ye, H., "Voltage-lift converters," in Essential DC/DC Converters, New York: Taylor & Francis, Chap. 2, 2006.
4. Wei, X., Tsang, K. M., and Chan, W. L., "DC/DC buck converter using internal model control," Electr. Power Compon. Syst., Vol. 37, pp. 320–330, 2009.
5. Lo, Y. K., Chen, J. T., Lin, C. Y., and Qu, S. Y., "Improved control-to-output characteristics of a PWM buck–boost converter," Int. J. Circ. Theor. Appl., Vol. 39, pp. 203–209, 2011.
6. Vuthchhay, E., and Bunlaksananusorn, C., "Dynamic modeling of a Zeta converter with state-space averaging technique," Proc. 2008 5th International Conference on Electrical Engineering/ Electronics, Computer, Telecommunications and Information Technology, pp. 969–972, Krabi, 14–17 May 2008.
7. Wong, L. K., and Man, T. K., "Small signal modeling of open loop SEPIC converters," IET Power Electron., Vol. 3, No. 6, pp. 858–868, 2010.
8. Fuad, Y., De Koning, W. L., and van der Woude, J. W., "On the stabil-ity of the pulse width-modulated Cuk converter," IEEE Trans. Circ. Syst. II: Express Briefs, Vol. 51, No. 8, pp. 412–420, 2004.
9. Hwu, K. I., and Yau, Y. T., "KY converter and its derivatives," IEEE Trans. Power Electron., Vol. 24, No. 1, pp. 128–137, 2009.
10. K. I. Hwu and Y. T. Yau, "A novel voltage-boosting converter: KY Converter," in Proc. IEEE APEC Conf., 2007, pp. 368-372.
11. K.I. Hwu and W. Z. Jiang, H. M. Chen, "Voltage Gain Enhancement of KY Converter", TENCON 2013-2013 IEEE Region 10 Conference (31194), 2014, IEEE, doi: 10.1109/T ENCON.2013.6718838.
12. K. I. Hwu, and Y. T. Yau," A KY Boost Converter", IEEE Transactions on Power Electronics, vol.25, pp. 2699 -2703, Nov. 2010
13. Wang, Jian-Min, Sen-Tung Wu, and Gwan- Chi Jane. "A Novel Con-trol Scheme of Synchronous Buck Converter for ZVS in Light-Load Condition", IEEE Trans. Power Electronics, vol. 26, pp. 3265 - 3273, April 2011.
14. R.M. Amarsagar Reddy and N. Lakshminarasamma, "Analysis, de-sign and implementation of soft switching in a synchronous convert-er", power and energy systems (ICPS), 2012, ©IEEE, doi: 10.1109/ICPES.2011.6156619.
15. Hwu, K. I., and Peng, T. J., "A novel buck–boost converter combining KY and buck converters," IEEE Trans. Power Electron., Vol. 27, No. 5, pp. 2236–2241, 2012.
16. Banaei, M. R., Ardi, H., and Farakhor, A., "Analysis and implementa-tion of a new single-switch buck–boost DC/DC converter," IET Pow-er Electron., Vol. 7, No. 7, pp. 1906–1914, 2014.
17. [17] Jose and Pramelakumari, K., "A Positive Output Buck Boost Con-verter Combining KY and SR-Buck Converters" IEEE International Conference on PICC, IEEE 2015, and doi: 10.1109/PICC.2015. 7455775.