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Voltage Control of KY Converter for Renewable EnergyApplications

Mr. Baburao. K. Bajari[1], Mr. Vedant. P. Bhosale[2], Mr. Rushikesh. M. Jadhav[3], Mr. Shubham. S. Manjare[4], Mr. Shubham. S. Bhandare[5]

Mr. S. N. Kamble[6]

[1,2,3,4,5]*Department of Electrical Engg. Sanjay Bhokare group of Institute, Miraj*

[6]*Assistant Professor, Department of Electrical Engg. Sanjay Bhokare group of Institute, Miraj*

ABSTRACT: Renewable energy is the energy that is collected from renewable resources and due to the rising depletion of fossil fuels, renewable energy is the source that humanity turns to for harnessing electrical power. The power so obtained often needs DC- better DC conversion for supplying the load properly. The boost converter is used currently for the chopper control in wind and solar power systems that provides a response characteristic that can be improved, by implementing a KY converter in place of the boost converter. The KY converter is a step-up DC-DC converter with transient response operating in Continuous Conduction Mode (CCM) always with low voltage ripple, non-pulsating current and the KY converter provides a larger voltage gain than the conventional boost converter.

In this topology where it is combined with buck boost converter but in this topology, DCM is also possible. Simulation of conventional boost converter and KY converter by MATLAB software is done for comparing the operation of the converters. KY converter is implemented in hardware to study the operation practically and to verify the feasibility of using the converter in renewable energy systems.

I. INTRODUCTION

In the modern society, DC-DC converters were widely used in portable electronic devices such as: mobile phones, laptops and digital still cameras (DSC). In order to converts the battery voltage into different voltage domains. For power supply applications using low voltage battery, in most instances, it is necessary uplift from low voltage to high voltage, thus a boost converter is usually applied, but with a pulsating output current leadingto a large voltage ripple. Moreover, the boost converter consists of a right-hand plane zero, which deteriorates the converter stability and transient response performances. Recently, a voltage-boosting converter has been proposed, named as KY converter. When this converter is operating in continuous conduction mode (CCM), it has a lot of advantages such as non-pulsating current, low output ripple, and good load transient response. Which can eliminate the problems exhibited by the boost converter thus a KY converter can be used instead of boost converter which will have better output response comparing with the traditional boost converter? Hence this KY converter can be employed for delivering power to the grid.

A solar panel is being used for delivering the DC supply and this DC voltage is stored in the battery. The voltage thus stored in the battery is then given to the KY converter for boosting its voltage level. Then the output of KY converter circuit is given directly to the load. By this a continuous output can be obtained with reduced ripple counts. The circuit of KY converter can be designed which consists of a diode, capacitors, a resistor and inductors. Thus, a better transient response can be obtained by using KY converter. Hence a ripple free output with comparatively high efficiency can be obtained which can be implemented for low power applications.

II. LITERATURE SURVEY

K. I. Hwu and Y. T. Yau, "A KY Boost Converter," For the applications of low battery voltage requiring high output voltage KY boost converter combined with traditionally synchronized Rectifier (SR) converter is recommended. This converter always operates in continuous conduction mode (CCM) but also both its input and output sides have individual inductors, thereby, making the corresponding current ripples small. Circuit topology, mathematical calculations and component selection criterion are presented and the experimental result shows the converter efficiency around 92% over the loading range [1].

H. J. Wen, C. Lam, W. Choi, C. Wong and M. Wong, "A 97.0% maximum efficiency, fast response, low voltage ripple KY boost converter for photovoltaic application," A novel negative output converter named KY boost converter is described with operating modes and supporting mathematical equations. The voltage control of such converter can be achieved by PWM control whereas the design includes calculation of energy transferring capacitor at input and output, inductor, diode, switching device selection and choice of switching frequency. MATLAB simulation results shows efficacy of KY converter in terms of voltage gain efficiency and ripple contents [2, 3].

K. I. Hwu and Y. T. Yau, "Two Types of KY Buck–Boost Converters," The simulation and hardware design of a DC-DC KY boost converter for PV generation system is presented in [4].

K. I. Hwu, Y. H. Chen and W. C. Tu, "Negative-output KY boost converter," The experimental results show that the system provides high power efficiency up to 97.0% and output voltage ripple of 0.5%. Thus a KY converter can be thought of as a high gain high efficiency and low output ripple converter. Such converter would be suitable of PV system where high efficiency converters are recommended. Unlike the traditional buck–boost converter, KY converter possesses fast transient responses, similar to the behavior of the buck converter with synchronous rectification. The basic operating principles of two types of KY buck boost converters are illustrated in detail and some experimental results are presented to demonstrate the effectiveness of the proposed topologies. Comparison of results of these two types is presented to demonstrate their characteristics for variations in duty cycle and voltage ratio [5].

K. I. Hwu and T. J. Peng, "A Novel Buck–Boost Converter Combining KY and Buck Converters," Many applications, including as portable gadgets, automobile electronic equipment, and so on, need voltage- bucking/boosting converters. This is because the battery's output voltage varies significantly, necessitating the inclusion of a switching power supply to handle the varying input voltage and creates the stable output voltage. The buck–boost converter has a positive output voltage and no right-half plane zero since it combines the KY converter with the standard SR buck by using the same power switches. It works in CCM by default, resulting inless fluctuation in duty cycle over the load range and hence easier converter management. This converter produces a non-pulsating output current, which reduces both the current stress on the output capacitor and the output voltage ripple [6].

K. I. Hwu, W. Z. Jiang and J. Shieh, "Study and simulation on control-to-output transfer function of KY boost converter," The transfer function approach helps in understanding the system from stability point of view. It also gives insights into possible variations in the output in terms of order of the system. The control to output transfer function constructed here contains the parameters of input voltage, two energy transferring capacitors, input and output inductors, duty cycle, output load, input and output currents, and switching frequency. Therefore, it is more practical to design the controller by using this transfer function [7].

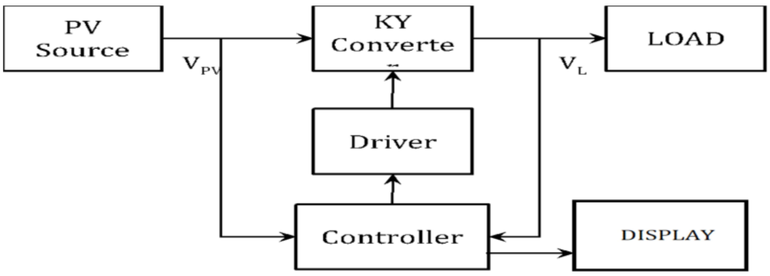
G. Joseph and V. Renjini, "Analysis and comparison of inductor coupled buck-boost converter

combining KY converter and SR buck converter," A detailed description and simulation result of A buck- boost converter combined with the KY converter and SR buck converter with coupled inductors is presented. This converter is modified from the buck-boost converter combining the KY converter and SR buck converter. The voltage conversion ratio of the modified converter is greater than that of the existing converter. The modified converter has improved conversion ratio and reduced switch voltage stress than the original converter and hence is more suitable [8].

Y. Chou, C. Song and K. I. Hwu, "On the design of fuzzy-controlled KY converter," A Fuzzy Logic controller design for second order KY converter is presented in [9].

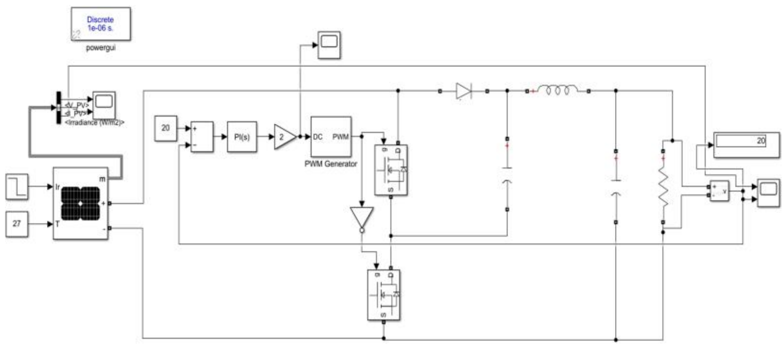
J. H. Jose and K. Pramelakumari, "A positive output buck boost converter combining KY and SR-buck converters," Experimental results show that the design achieves faster transient load responses and lower output voltage ripples as compared with the conventional boost converters. Operating principle and closed loop analysis of A Positive Output Buck Boost Converter Combining KY and SR Buck Converter is presented. The experimental result shows that closed loop control strategy gives constant output voltage in case of variations in input voltage. The resulting overshoots and under-shoots are also very low. Such converter structure compared to traditional buck-boost converter maximizes efficiency, minimizes ripples and associated cost [10].

III. BLOCK DIAGRAM

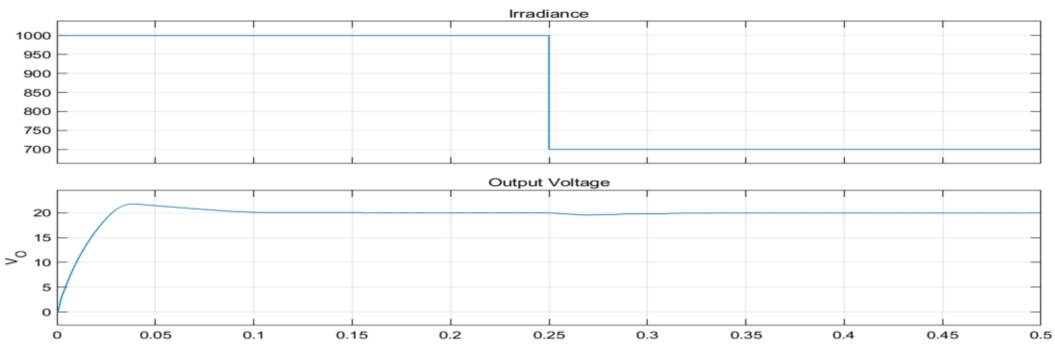


The block diagram of proposed KY converter-based PV system is shown in figure. The output voltage of PV panel and the load voltage is taken as feedback for the controller. The controller generates PWM pulses to compensate for error between desired voltage and actual voltage. A driver circuit is required to provide the necessary isolation between low power controller circuit and the high-power circuit of the converter. The KY converter will be designed by considering the rating of PV panel and the load. It is proposed to regulate the output voltage of KY converter by PI control. This controller will regulate the output voltage by controlling the duty cycle of PWM pulses.

IV. RESULTS



The MATLAB simulation model of KY converter is shown in above figure. Here, the output voltage of the converter is to be regulated to reference of 20V. hence a constant reference value of 20 is taken. The actual KY converter voltage is taken as feedback and given to the difference block to generate the error signal to the PI controller. The PI controller generated the duty cycle for PWM generator in order to reduce the error signal to zero. The PWM generator generated the PWM control signal for the MOSFETs and thereby the voltage of the converter is adjusted.



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As shown in the figure above, the input to the system is solar radiations. At the start the solar radiations is at 1000 Lux. And at time instance t = 0.25, the solar radiations fall to 700 Lux. The closed loop controller in all thecases is observed to regulate the output voltage of the converter to 20V.

V. FUTURE SCOPE

In terms of future scope, several trends and advancements can be anticipated:

1. Efficiency Improvements: Continuous efforts will be made to enhance the efficiency of KY converters to maximize the energy harvested from solar panels. This includes reducing losses in the conversion process through better semiconductor materials, advanced control algorithms, and improved circuit designs.
2. Miniaturization and Integration: As with many electronic components, there will likely be a trend towards miniaturization and integration of KY converters. This could involve advancements in power semiconductor technology, allowing for higher power density converters, as well as integration of additional functionalities such as maximum power point tracking (MPPT) directly into the converter.
3. MPPT Integration: While MPPT is often implemented as a separate component in PV systems, there's potential for its integration into KY converters. This integration could simplify system design, reduce component count, and improve overall efficiency by optimizing the voltage conversion process based on real-time solar conditions.
4. Smart and Adaptive Control: Future KY converters may incorporate more sophisticated control algorithms that adapt to changing environmental conditions and load requirements. Machine learning and artificial intelligence techniques could be employed to optimize converter operation and maximize energy yield under varying conditions.
5. Compatibility with Energy Storage Systems: With the increasing popularity of energy storage systems such as batteries, future KY converters may be designed to seamlessly integrate with these systems. This could involve bidirectional operation, allowing the converter to efficiently charge or discharge batteries as needed, thereby enhancing the overall flexibility and resilience of the PV system.

VI. CONCLUSION

The voltage regulation provided by KY boost converters comes with a set of merits and demerits. On the positive side, they excel in high efficiency, compact design, and flexibility across a wide input voltage range. Their regulated output voltage, quick response to load changes, and low output ripple make them suitable for diverse electronic applications. However, challenges such as complex control circuitry, potential EMI issues, and voltage stress on components must be considered. Understanding the specific requirements of the application is crucial in determining whether a KY boost converter is the optimal choice for achieving the desired voltage regulation, balancing performance, and potential drawbacks. **The developed control system effectively regulates the output voltage of a KY converter,**

offering several key benefits: [1] Accurate Voltage Regulation: PI control ensures the output voltage closely follows the desired reference voltage, minimizing deviations and fluctuations. **[2]** Reduced Voltage Ripple: The proportional (P) term in the PI controller promptly responds to voltage errors, while the integral (I) term eliminates steady-state errors, leading to a cleaner and more stable output voltage with minimal ripple.

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