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MATLAB/SIMULINK based simulations of KY converter for PV panels powered led lighting system

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ABSTRACT

The main objective of this research work is to develop KY conveter topology for renewable energy sources.Solar energy is the readily available and is the cheapest form of energy. It is non-polluting and environment friendly. The development of high static gain DC-DC converters is an important research area due to the crescent demand of this technology for several applications supplied by low DC output voltage power sources. It is used to provide the uninterruptable power supply and battery powered to the system. So here, step-up DC-DC converters based on the KY converter are proposed for LED lighting systems. The proposed topologies present high voltages and high efficiency for low input voltage and high output voltage applications. The simulation results of the proposed topology have been presented using MATLAB/SIMULINK software.

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1. INTRODUCTION

The growth of power systems emphasizes all aspects of electrical energy, innovation in power generation, distribution and Utilization , alternative resources, and efficient power electronic devices. Latest power electronic devices plays vital role for the power conversion, delivery, and usage of energy in the power system network. The activity ranges from controls for large utility systems to energy harvesting devices for micro-sensors. Electrical energy continues to be the foundation of the modern economy. The growth of solar energy, wind energy, and other resources, combined with trends such as electric and hybrid vehicles will a have profound impact on global society. Large number of the simulation study of power systems and power electronics converters were reported [1-32]. The Photo Voltaic (PV) power generation system is gaining more and more visibility, while the worlds power demand is increasing and awareness of the importance of protecting the global environment has been growing. The PV systems are modular, hence the major advantage of these systems is that they can be simply adopted in existing buildings and can be installed anywhere. In addition, manufacturers have designed various models, which can be placed in different types of houses or buildings to achieve better performance.

An interesting work [33], derives the voltage loop gain and the closed loop transfer function from reference voltage to output voltage for the voltage-loop of a pulse width modulated (PWM) dc-dc converter operating in continuous-conduction mode (CCM) with peak current-mode control (PCM). In PV system topology, a series connected to PV module is used to create a high voltage string connected to the DC-DC converter [34-37]. However, under real conditions the performance of this scheme is negatively affected if all its modules are in homogeneously illuminated. All the modules in a series array are forced to carry the same current even though a few modules, under shade, produce less photocurrent. The shaded modules may get reverse biased, acting as loads, and dissipating power from fully illuminated modules in the form of heat. On the other hand, the inhomogeneous illuminated part makes PV array have multiple power peaks. To avoid thermal overload, substrings of cells inside the interconnection circuit of modules are bridged by bypass diodes. Although it is possible for string circuits to reduce the influence of partial shadow to some extent, they could not solve the maximum power point tracking (MPPT) problem in the shaded string circuit because the presence of the PV array has multiple power peaks due to the existing MPPT schemes which are unable to discriminate between the local and global power peaks [38]. To overcome this problem a series string of the DC-DC converter with corresponding string current diverter circuits based on buck-boost converter is used. The string current diverter circuit is independently utilized to balance the output voltage of the DC-DC converter under shadow conditions. The proposed circuit enables the individual PV modules to operate effectively at the MPPT by imposing an optimum ratio under any conditions. An interesting work on KY Converter is presented in [39]. In this research paper the authors have proposed the boundary for the DCM operation region, DCM dc voltage and small-signal transfer functions. Another work on KY converter is proposed by K. I. Hwu et.al in [40]. This work focuses on KY Converter and Its Derivatives. Latest works on KY converter has been reported in [41-43].

2. THE PROPOSED SOLUTION: PROPOSED KY CONVERTER MODEL

The proposed block diagram of the system is shown in Figure 1. The designed KY converter is implemented in standard 0.18-µm CMOS technology, consisting three power transistors, a filter network, and a current mode control network, demonstrating excellent performance. This paper is organized as follows. Section II presents the study of an integrated KY converter in both system and circuits level, including operating modes, effects of parasitic resistances, transistor sizes, power loss, output voltage ripples, design of power components, and the load and line regulations [44]. In addition, various aspects of the KY converter are also theoretically analyzed to compare with boost converter to show its advantages. Section III presents the circuit implementation details of the proposed integrated KY converter, based on the analysis developed in Section II. The measurement results and comparison with recent works are provided in Section IV. Finally, Section V concludes this paper.

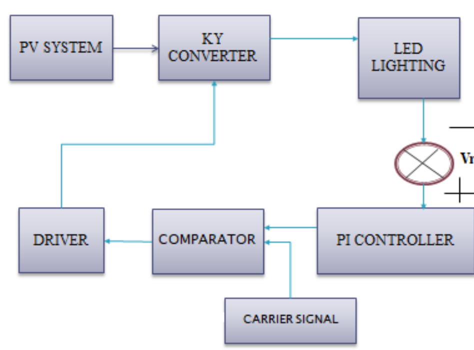

Figure 1. Block diagram of the proposed model

2.1. PV panel

The Monocrystalline PV panels are used. 40 cells are connected in series to form a single module. Voltage of single cell is 0.6V so the voltage of a single module is 24V. In this proposed method 3 modules are used.

2.2. MPPT (Incremental Conductance)

The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right, as can be seen in the figure $\Delta V/\Delta P= (\Delta I/\Delta P)$ at the MPPT

a. ΔV/ΔP< (ΔI/ΔP) on the left
b. ΔV/ΔP> (ΔI/ΔP) on the right

By comparing the increment of the power vs. the increment of the voltage (current) between two consecutives samples, the change in the MPP voltage can be determined. A scheme of the algorithm is shown in the Figure 2**.**

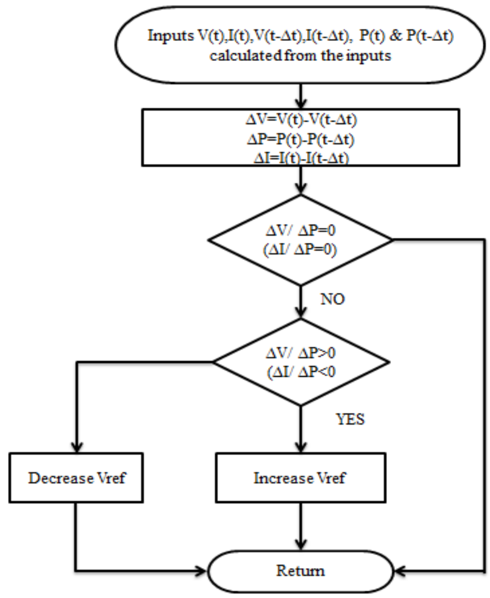

Figure 2. MPPT algorithm

3. KY CONVERTER CIRCUIT DIAGRAM

The circuit diagram of the KY Convereter is represented in Figure 3. The KY buck-boost converter reported in has many good features when compared to other DC-DC converters for portable applications. The KY buck-boost converter uses only two switches, which are operated in synchronous way. This reduces the cost and size of the circuit and can operate in bidirectional mode. The polarity of the output voltages of buck-boost, Zeta, SEPIC, Cuk, and single-switch buck-boost converters are opposite in polarity with input voltage whereas the KY buck - boost converter provides the output voltage of same polarity with input voltage. The KY buck boost converter does not have RHP zero that increases stability and transient response. A simple voltage mode analog controller is proposed in this work for the KY buck-boost converter to regulate the output voltage.

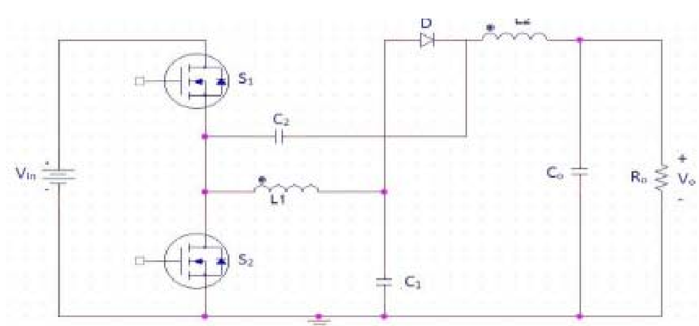

Figure 3. Circuit diagram of KY converter

3.1. Mode 1(S1 ON, S2 OFF):

In Figure 4, the input voltage provides energy for C1 and L1 making C1 getting charged and L1 to be magnetized as shown in equivalent circuit diagram, At the same moment, the input voltage along with capacitor C2 supplies the energy for inductor L2 and to the output which causes C2 to be discharged and L2 getting magnetized.

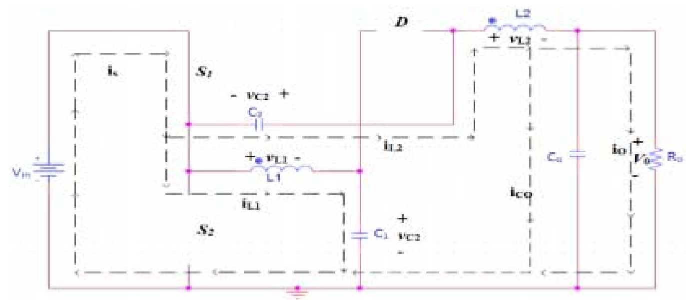

Figure 4. Mode 1(S1 ON, S2 OFF)

3.2. Mode 2(S1 OFF, S2 ON):

The equivalent circuit diagram during this mode of operation as show in Figure 5. The energy stored in inductor L1 and capacitor C1 are released to capacitor C2 and to the output via inductor L2 causing C1 to be discharged and L1 to be demagnetized. At the same moment, the voltage across L2 is vC2 minus Vo, thus making C2 to be charged and L2 being demagnetized.

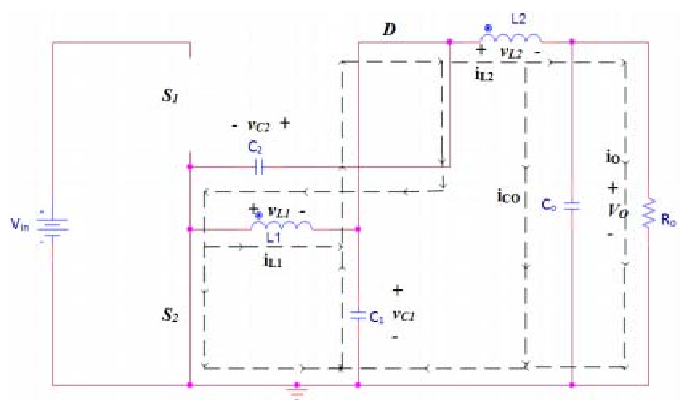

Figure 5. Mode 2 (S1 OFF, S2 ON)

3.3. PV panel

In electronics, a driver is an electrical circuit or other electronic component used to control the KY converter. They are usually used to regulate current flowing through a circuit or to control other factors such as other components, some devices in the circuit. The term is often used, for example, for a specialized integrated circuit that controls high-power switches in switched-mode power converters.

4. SIMULATION DIAGRAM OF PROPOSED KY CONVERTER CIRCUIT

The simulation diagram of KY converter is shown in the Figure 6. The KY buck-boost converter with the PI controller is simulated in MATLAB/SIMULINK as shown in Figure 4. The output voltage when operated in buck and boost mode in MATLAB simulation are shown in Figure 5 respectively.

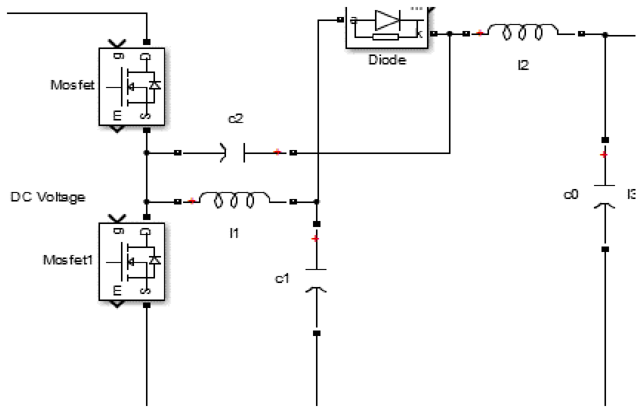

Figure 6. Simulation diagram of proposed circuit

4.1. Simulation diagram of PV panel

The subsystem of PV panel is shown in the Figure 7. The solar cell is a physical system it cannot be directly connected to the Simulink model so a converter is used in between them to connect the two systems.

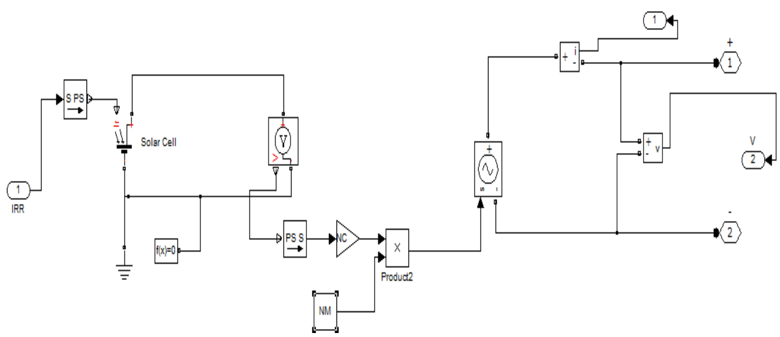

Figure 7. Simulation diagram of PV panel

4.2. Simulation diagram of MPPT technique

The simulation diagram of MPPT technique is show in the Figure 8. In the proposed method Incremental Conductance Algorithm is used to track the MPPT. In this MPPT the maximum power is tracked by comparing the previous value of voltage, current and power with the recent values and the duty cycle is given accordingly.

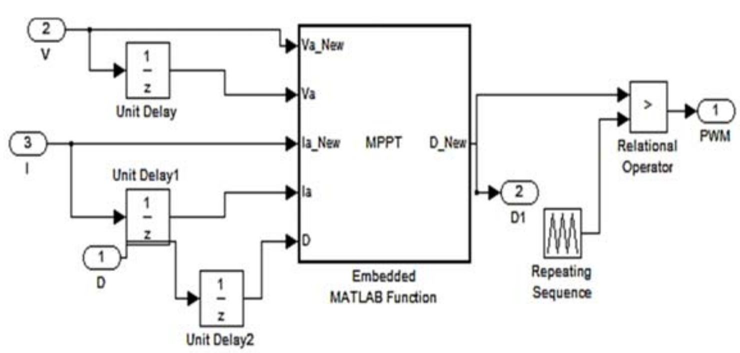

Figure 8. Simulation diagram of MPPT technique

4.3. Simulation diagram of KY converter

The simulation diagram of KY converter is shown in the Figure 9. The KY buck-boost converter with the PI controller is simulated in MATLAB/SIMULINK. The output voltage when operated in buck and boost mode in MATLAB simulation are shown in Figure 5 respectively.

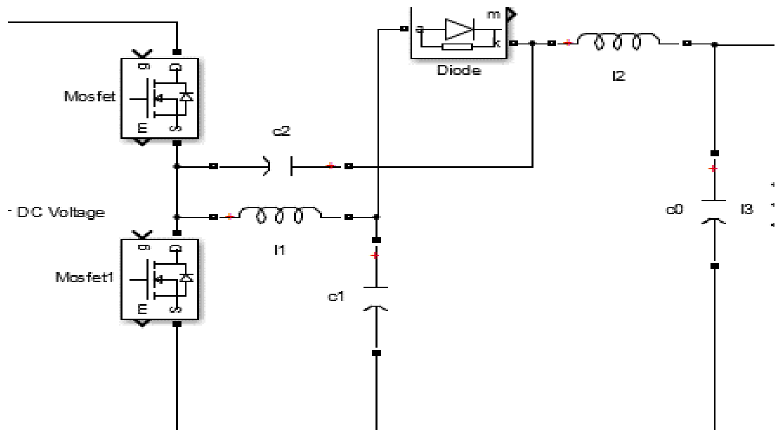

Figure 9. Simulation diagram of modified SEPIC converter

4.4. Simulation diagram of string current diverter

The simulation diagram of String Current Diverter is shown in the Figure 10. The String Current Diverter diverters back the output current of the DC-DC converter in order to maintain the output voltage of the DC-DC converters constant. String current diverter is switched ON or OFF according to balance or imbalance of output currents of PV modules. With the existing measures of output currents of PV modules, an error calculation is carried out and compared with a threshold value ε and the SCD is switched ON or OFF accordingly.

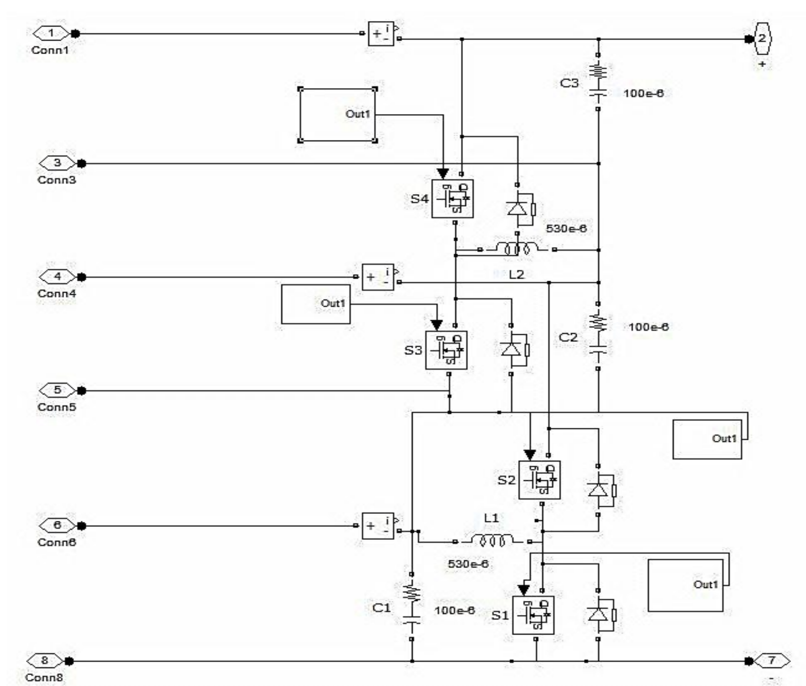

Figure 10. Simulation diagram of string current diverter

5. RESULTS AND DISCUSSIONS

The output current of PV panel is shown in Figure 11.

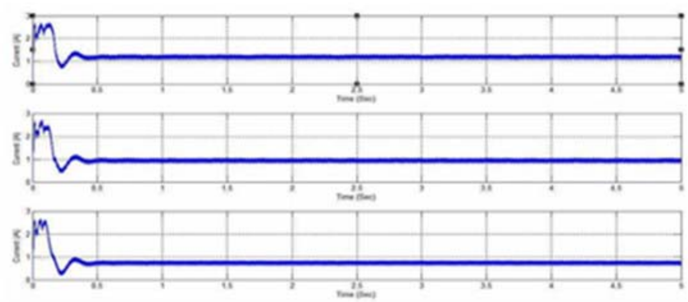

Figure 11. PV panel current (X-axis 1 div=0.5s Y-axis 1 div=1A)

The output voltage of KYconverter is shown in Figure 12 and Figure 13.

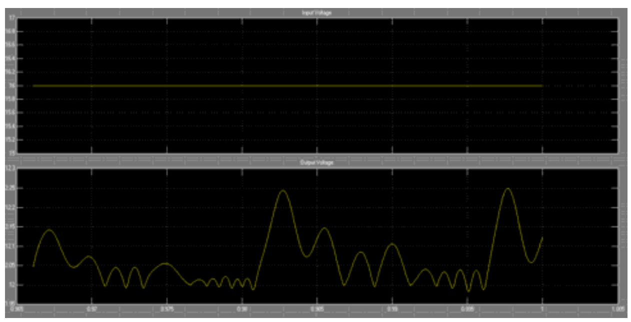

Figure 12. KY converter BUCK operation

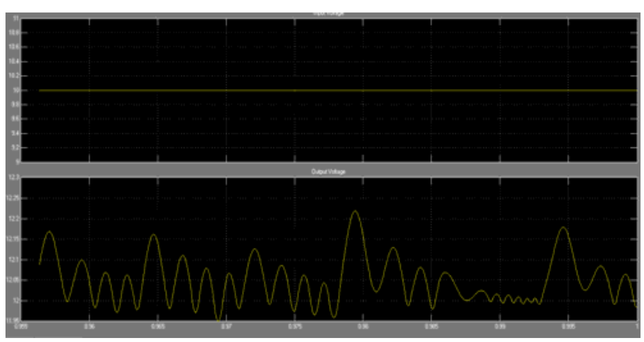

Figure 13. KY converter BOOST operation.

5.1. Drawbacks in this system

If the input power is higher than the required one, then the circuit components may lead to fault.

5.2. Advantages of Proposed System

a. KY boost converter has higher voltage ratio than the traditional boost converter does.
b. Besides, the input and output inductor currents are continuous, different from the traditional boost converter.
c. Hence this converter is very suitable for low ripple applications.

6. CONCLUSIONS

This paper presents design and implementation of the KY buck boost converter. A simple PI controller is proposed and designed to regulate the output voltage of the converter. Exclusive Simulation results are presented to verify the functionality of the converter with the controller under steady state and dynamic conditions.The proposed conveter design and simulation results will be useful for power system and power electronics Engineers to explore the possibilities of developing hardware and suitable for real time high voltage power transmission. KY conveter will play a vital role in integrating intermittent renewable energy sources effectively in to the existing power grid.

REFERENCES

[1] Sunil Thomas, K.Nithiyananthan, "A Novel method to implement MPPT algorithms for PV panels on a MATLAB/SIMULINK environment," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10(4), pp. 31-40, 2018

[2] Gowrishankar. K., Sunil Thomas, K. Nithiyananthan, "Wireless integrated-sensor network based subsea tunnel monitoring system," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10(12), pp. 647-658, 2018.

[3] Gowrishankar. K., K. Nithiyananthan., M. Priyanka, Sunil Thomas, "GSM based dual power enhanced LED display notice board with motion detector," *International Journal of Engineering and Technology (UAE)*, vol. 7(2.8 Special Issue 8), pp. 559-566, 2018.

[4] Syahrel Emran Bin Siraj, Tan Yong Sing, Raman Raguraman, Pratap Nair Marimuthu, K. Nithiyananthan, "Application of cluster analysis and association analysis model based power system fault identification, *European Journal of Scientific Research*, vol. 138, pp16-28, 2016.

[5] K. Nithiyananthan, Pratap Nair, Raman Raguraman, Tan Yong Sing, Syahrel Emran Bin Siraj, "Enhanced R package-based cluster analysis fault identification models for three phase power system network," *International Journal of Business Intelligence and Data Mining*, vol. 14, pp. 106-120 2019.

[6] Sekath Varma, K. Nithiyananthan, "MATLAB simulations based identification model for various points in global positioning system," *International Journal of Computer Applications*, vol. 138(13), pp15-18, 2016.

[7] S. Samson Raja, R. Sundar, A. Amudha, K. Nithiyananthan, "Unit commitment calculator model for three phase power system network, "*International Journal of Power and Renewable Energy Systems*, vol. 3(1), pp.37-42, 2016.

[8] K. Gowrishankar, K. Nithiyananthan, Mani Priyanka, Venkatesan, G., "Neural network based mathematical model for feed management technique in aquaculture," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 9(18), pp. 1142-1161, 2017.

[9] Sing, Tan Yong and Bin Siraj, Syahrel Emran and Raguraman, Raman and Marimuthu, Pratap Nair and Nithiyananthan, K, "Cosine similarity cluster analysis model based effective power systems fault identification," *International Journal of Advanced and Applied Sciences*, vol. 4(1), pp. 123-129, 2017.

[10] Pratap Nair, Nithiyananthan, K., Dhinakar, P, "Design and development of variable frequency ultrasonic pest repeller," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 9(12), 2017, pp. 22-34.

[11] K. Nithiyananthan, Sundar, R., Ranganathan, T., Samson Raja, S., "Virtual instrumentation based simple economic load dispatch estimator model for 3-phase power system network," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 9(11), pp. 9-15, 2017.

[12] K. Nithiyananthan, T. Samson Raja, Sundar, R., Amudha, A., "Virtual stability estimator model for three phase power system network," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 4(3), pp. 520-525, 2016.

[13] Pratap Nair, M., K. Nithiyananthan, "An effective cable sizing procedure model for industries and commercial buildings," *International Journal of Electrical and Computer Engineering*, vol. 6(1), pp. 34-39, 2016.

[14] Pratap Nair, M., K. Nithiyananthan, "Feasibility analysis model for mini hydropower plant in Tioman Island," *Distributed Generation and Alternative Energy Journal*, vol. 31(2), pp. 36-54, Malaysia, 2016.

[15] K. Nithiyananthan, Umasankar, "Environment friendly voltage up-gradation model for distribution power systems, *International Journal of Electrical and Computer Engineering*, vol. 6(6), pp. 2516-2525, 2016.

[16] Sureshkumaar, G., Kannan, N., Thomas, S., Karthikeyan, S.P., "Matlab/simulink simulations based modified sepic DC to DC converter for renewable energy applications," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 11(4), pp. 285-295, 2019.

[17] G. Venkatesan, K. Nithiyananthan, "Static and transient thermal analysis of power factor converters in switched reluctance motor drive," *Journal of Advanced Research in Dynamical & Control Systems*, USA, vol. 10(13), pp. 1656-1662, 2018.

[18] K. Nithiyananthan, Ramachandran, V., "Effective data compression model for on-line power system," *International Journal for Engineering Modelling*, vol. 27(3-4), pp. 101-109, 2014.

[19] K. Nithiyananthan, Ramachandran, V., "Distributed mobile agent model for multi area power systems automated online state estimation," *International Journal of Computer Aided Engineering and Technology*, vol. 5(4), pp. 300-310, 2013.

[20] K. Nithiyananthan, Ramachandran, V., "Versioning-based service-oriented model for multi-area power system online economic load dispatch," *Computers and Electrical Engineering*, vol. 39(2), pp. 433-440, 2013.

[21] K. Nithiyananthan, Ramachandran, V., "Location independent distributed model for on-line load flow monitoring for multi-area power systems," *International Journal for Engineering Modelling*, vol. 24(1-4), pp. 21-27, 2011.
[22] K. Nithiyananthan, Loomba, A. K., "MATLAB/simulink based speed control model for converter controlled DC drives," *International Journal for Engineering Modelling*, 24(1-4), pp. 49-56, 2011.
[23] Thomas, S., K. Nithiyananthan, Eski. A., "Investigations on transient behavior of an energy conservation chopper fed DC series motor subjected to a change in duty cycle (2019)," *Journal of Green Engineering*, vol. 9(1), pp. 92-111, 2019.
[24] K. Nithiyananthan, Ramachandran, V., "A plug and play model for JINI based on-line relay control for power system protection," *International Journal for Engineering Modelling*, vol. 21(1-4), pp. 65-68, 2008.
[25] K. Nithiyananthan, Ramachandran, V., "A distributed model for capacitance requirements for self-excited induction generators," *International Journal of Automation and Control*, vol. 2(4), pp. 519-525, 2008.
[26] Nithiyananthan K, Ramachandran.V, "Component model simulations for multi - area power system model for on-line economic load dispatch," *International Journal For Emerging Electric Power Systems*, U.S.A, vol. 1(2), Art No 1011, 2008.
[27] K. Nithiyananthan, Elavenil. V, "CYMGRD based effective earthling design model for substation, "*International Journal For Computer Applications In Engineering Sciences Asia*, vol. I(3), pp. 341-346, 2011.
[28] K. Nithiyananthan, Ramachandran, V., "Distributed mobile agent model for multi-area power system on-line economic load dispatch," *International Journal for Engineering Modelling*, vol. 17(3-4), pp. 87-90, 2004.
[29] Youssef A. Mobarak, A. M. Hemeida, Nithiyananthan Kannan, "Voltage and frequency based load dependent analysis model for egyptian power system network, "*Journal of Advanced Research in Dynamical & Control Systems*, USA, vo.l 11(6), pp. 971-978, 2019.
[30] Low Kak Hau, Gowrishankar, Nithiyananthan. K, "Development of prototype model for wireless based control pick and place robotic vehicle," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, Asia, vol. 14(1), pp. 110-115, Apr 2015.
[31] K. Nithiyananthan, Ramachandran, V., "A distributed model for multi-area power systems on-line dynamic security analysis," *IEEE Region 10 Annual International Conference*, Proceedings/TENCON, vol. 3, pp. 1765-1767, 2002.
[32] K. Nithiyananthan, Ramachandran, V., "EJB based component model for distributed load flow monitoring of multi-area power systems," *International Journal for Engineering Modelling*, vol. 15(1-4), pp. 63-67, 2002.
[33] 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(1), pp. 99-105, 2006.
[34] 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.
[35] Luo, F. L. and Ye, H., "Voltage-lift converters," in *Essential DC/DC Converters*, New York: Taylor & Francis, vol. 2, 2006.
[36] 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.
[37] Lo, Y. K., Chen, J. T., Lin, C. Y. and Qu, S. Y., "Improved control-tooutput characteristics of a PWM buck-boost converter, *Int. J. Circ. Theor. Appl*., vol. 39, pp. 203-209, 2011.
[38] Kadri, Riad, Jean-Paul Gaubert, and Gerard Champenois. "Nondissipative string current diverter for solving the cascaded DC-DC converter connection problem in photovoltaic power generation system", *IEEE Transactions on Power Electronics*, vol. 27(3), pp. 1248-1252, 2012.
[39] W. Zeng et al., "DCM operation analysis of KY converter," in *Electronics Letters*, vol. 51(24), pp. 2037-2039, 19 11, doi: 10.1049/el.2015.2241, 2015.
[40] K. I. Hwu and Y. T. Yau, "KY converter and Its derivatives," in *IEEE Transactions on Power Electronics*, vol. 24(1), pp. 128-137, doi: 10.1109/TPEL.2008.2009178, Jan 2009.
[41] W. Zeng, C. Lam, S. Sin, F. Maloberti, M. Wong and R. P. Martins, "A 220-MHz bondwire-based fully-integrated KY converter with fast transient response under DCM operation," in *IEEE Transactions on Circuits and Systems I*: Regular Papers, vol. 65(11), pp. 3984-3995, doi: 10.1109/TCSI.2018.2854370, Nov 2018.
[42] 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," *2018 IEEE International Conference on Industrial Electronics for Sustainable Energy Systems (IESES)*, Hamilton, pp. 71-75, 2018.
[43] V. Rallabandi, O. M. Akeyo, N. Jewell and D. M. Ionel, "Incorporating battery energy storage systems into multi-MW grid connected PV systems," in *IEEE Transactions on Industry Applications,* vol. 55(1), pp. 638-647, doi: 10.1109/TIA.2018.2864696, Jan.-Feb. 2019.
[44] Zhang, Y., Li, D., Lu, H., Fan, S., Chen, Z., Wang, Y., & Geng, L., "Analysis and implementation of a high-performance-integrated KY converter," *IEEE Transactions on Power Electronics*, vol. 32(12), pp. 9051-9064, 2017.