VOL. 10, NO. 7, APRIL 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A SURVEY ON CONVERTER TOPOLOGIES IN VARIOUS APPLICATIONS

S. Sathiyamoorthy[1] and M. Gopinath[2]
[1]St. Peter's University, Chennai, India
[2]Dr. N. G. P. Institute of Technology Coimbatore, India
E-Mail: sathya2980@gmail.com

ABSTRACT

In most scenarios, several categories of DC-DC converter topologies have been utilized in the motor drive systems. On account of their irrespective distinctions, they all try to input the maximum quantity of power from the system with as diminutive loss of energy as possible inside the circuit itself. DC-DC converter is a kind of switching converter which fundamentally offers a certain quantity of ripple in the current, while it results in reducing the effectiveness. In general, this ripple is diminished by using a filter at the output terminals. At the same time as this is a solution, the magnitude, cost and life of the filter is completely based on the types of converter employed. Converters like buck, boost, buck-boost and cuk are derived topologies are employed in numerous applications are discussed here. This survey investigates and examines about the performance of the various converters in several applications especially in BLDC motors.

Keywords: converters boost and buck converters, cuk converters, motor applications.

1. INTRODUCTION

Converter in power electronics area is an electrical device that transforms power from of an electrical signal or power source, by transforming it from one form to another form. In general, converter can be categorized into four categories which are rectifier, inverter, chopper and cyclo converter [1, 2]. Converters are employed for applications like rectification of AC to DC, or an inversion from DC to a controlled frequency of AC to provide variable speed AC motor, interfacing DC power sources to AC circulation systems like photoelectric devices and also constructions of DC from AC power for subway and for controlled DC voltage for the purpose of speed control of DC motor in several industrial applications and etc.

On the whole, power electronic converters can be categorized in to two sub-categories [3].

- Indirect Converters - The input is rectified, smoothed by the use of an intermediate DC link capacitor and inverted by means of an array of power electronic switches
- Direct Converters - The output is synthesized openly from the input by piecewise sampling of input signal by means of an array of power electronic switches.

Indirect converter includes two phases of conversion. The initial stage comprise a bridge rectifier, in which, the three phase AC supply is supplied to the rectifier in order that the rectifier carries out the operation of AC to DC conversion. Following this conversion, it was provided to the energy storage component which is typically a capacitor. The inverter executes the task of DC to AC conversion which is given at the second stage. The intermediate DC link capacitor employed in indirect conversion topologies, needs a large space for its installation, which results in bulkier and heavier converter housing.

A direct AC-to-AC converter does not include DC link capacitor. Converter has an uncomplicated structure and several attractive characteristics. The three phase matrix converter is a single stage converter which has 9 bi-directional switches, to connect, directly a three phase voltage source to a three phase load [4].

A DC/DC converter is employed in power supply systems to supply a regulated output DC voltage. There are 4 main categories of converters, typically called the Buck, Boost, Buck-Boost and Cuk converters. The Buck converter is employed for stepping down the voltage level, at the same time the Boost converter is employed for stepping up voltage step-up. The Buck-Boost and Cuk converters can be employed for either stepping-down or stepping-up the voltage level. DC/DC converters are nonlinear and time invariant system.

DC-DC converters are kind of electronic devices which is employed when want to transform DC electrical power efficiently from one voltage level to another level. In DC-DC converters the impedance level of input energy is transformed from one level to another. DC/DC converter is largely employed in a system where a regulated voltage supply is required to the circuit. The converter controls the DC link voltage by means of capacitive energy transfer which results in non pulsating input and output currents.

In this work, designed a novel cuk converter with condensed number of power utility devices. This work also examines the functionality of the cuk converter operated in buck mode with constant DC current and variable DC voltage dependent on the corresponding speed error. The main objective of this research work is to analyze cuk converter proposed in various application to evaluate the performance of it.

2. BACKGROUND STUDY

Brushless Direct Current (BLDC) motors are one of the motor types quickly attaining the popularity. BLDC motors are employed in industries like Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. Since the name implies, BLDC motors do not use brushes for commutation; as an alternative, they are electronically commutated. BLDC motors have several advantages over brushed DC motors and induction motors like, better speed against torque characteristics, high dynamic response, better efficiency, long operating life, noiseless operation, elevated speed ranges. Within the last decade, the research and improvement on BLDCM drives have been concentrated on the motor topology design and optimization in addition to the motor control strategies. On the other hand, most of these converter topologies utilize the hard-switching technique which causes high switching losses and severe electromagnetic interference (EMI).

In [5] presented a new low cost, highly efficient, reliable and compact motor drive topology. The drives consist of a three-phase permanent magnet brushless DC (BLDC) motor, a soft switching dc-dc converter and a three-phase inverter containing six silicon controlled rectifiers (SCRs). A micro controller or a digital signal processor (DSP) will be used to control the overall system. The proposed system is fault tolerant doe to its current regulated nature, where it can even withstand a solid short circuit at its output terminals. The drive is low cost with respect to the commercially used IGBT-based systems. Since all the switches used in the output three phase inverter are current commutated, and the dc-dc converter uses soft-switching techniques, this drive has much lower switching losses than the conventional PWM drive.

R.Shanmugasundram *et al*, [6] presented a compact, economical high-speed driver and converter circuits and a pulse width modulation (PWM) control strategy implemented in a versatile Aduc812 micro controller for achieving better performance with low cost, compact BLDC drive using a versatile Aduc812 microcontroller is designed, implemented and tested. Also implemented several protective functions like over current protection, over voltage, and thermal protection of BLDC motor.

Roshan Kumar (2014) [7] presents a new soft-switching boost converter has been proposed that uses an auxiliary switch and resonant circuit. The main switch performs soft switching under the zero-voltage condition by using a resonant capacitor and inductor, as does the auxiliary switch. The efficiency, which is about 91% in hard switching, increases to about 96% in the proposed soft-switching converter.

Bikram Das *et al*, [8] has studied a comparative study of CSI fed BLDC motor using Boost and Buck Converter Both the strategy significantly reduces the switching loss and cost thereby increasing the speed and efficiency of the BLDC motor drive system. The study is verified with the simulation results.

Nesapriya and Rajalaxmi (2013) [9] proposed a method based on the bridgeless single-phase AC–DC Power Factor Correction (PFC) converters with Fuzzy Logic Controller. The proposed topologies are designed to work in Discontinuous Conduction Mode (DCM) to achieve a unity power factor and low total harmonic distortion of the input current. Additional reduction in the size of the PFC inductor and EMI filter is necessary.

Singh and Singh (2011) [10] have proposed a buck–boost converter feeding a BLDC motor based on the concept of constant dc link voltage and PWM-VSI for speed control which has high switching losses. A single-ended primary-inductance converter (SEPIC)-based BLDC motor drive has been proposed by Gopalarathnam and Toliyat (2003) [11], but it leads to higher losses in VSI due to PWM switching and a higher number of current and voltage sensors which restricts its applicability in low-cost application.

Singh and Singh (2012) have proposed a Cuk converter-fed BLDC motor drive with the concept of variable dc link voltage. This reduces the switching losses in VSI due to the fundamental switching frequency operation for the electronic commutation of the BLDC motor and to the variation of the speed by controlling the voltage at the dc bus of VSI. A Continuous Conduction Mode (CCM) operation of the Cuk converter has been utilized which requires three sensors and is not encouraged for low cost and low power rating.

Vashist and Bhim (2014) [12] have presented a PFC bridgeless (BL) buck–boost converter-fed BLDC motor drive as a cost-effective solution for low-power applications. An approach of speed control of the BLDC motor by controlling the dc link voltage of the VSI is used with a single voltage sensor. This facilitates the operation of VSI at fundamental frequency switching by using the electronic commutation of the BLDC motor which offers reduced switching losses. A BL configuration of the buck–boost converter is proposed which offers the elimination of the diode bridge rectifier, thus reducing the conduction losses associated with it. A PFC BL buck–boost converter is designed to operate in Discontinuous Inductor Current Mode (DICM) to provide an inherent PFC at ac mains.

In [13] presents a novel ac/dc converter based on a quasi-active power factor correction (PFC) scheme. In the proposed circuit, the power factor is improved by using an auxiliary winding coupled to the transformer of a cascade dc/dc fly back converter. The auxiliary winding is placed between the input rectifier and the low-frequency filter capacitor to serve as a magnetic switch to drive an input inductor. Since the dc/dc converter is operated at high-switching frequency, the auxiliary windings produce a high frequency pulsating source such that the input current conduction angle is significantly lengthened and the input current harmonics is reduced. It eliminates the use of active switch and control circuit for PFC, which results in lower cost and higher efficiency. Finally a DC motor load is applied and simulation results are presented.

Francis and Krishnan, (2014) [14] developed a brushless DC motor control technique without using any sensors. Back emf of motor is considered as a parameter for commutation. Also this system incorporates cuk converter as a power factor correction converter for PMBLDC motor fed through a diode bridge rectifier from a single phase AC mains. Three phase VSI is used in this system as an electronic commutator for BLDC motor based compressor in an air conditioner. Here the proportionality between Dc link voltage and speed is considered and speed control in this system is attained by maintaining this proportionality. Wide range speed control is possible by controlling the dc link voltage.

A systematic method for deriving three-port converters (TPC) from the full bridge converter (FBC) was proposed in (Hongfei Wu *et al*., 2012) [15]. The three port full bridge converter (TP-FBC) was obtained by splitting the two switching legs of the FBC into two switching cells with different sources and allows a dc bias current in the. By using this systematic method, a novel full bridge TPC was developed for renewable power system applications which feature simple topologies and control, a reduced number of devices, and single stage power conversion between any two of the three ports. This FB-TPC consists of two bidirectional ports and an isolated output port. The primary circuit of the converter functions as a buck-boost converter and provides a power flow path between the ports on the primary side. The FB-TPC can adapt to a wide source voltage range, and tight control over two of the three ports can be achieved while the third port provides the power balance in the system. Furthermore, the energy stored in the leakage inductance of the transformer is utilized to achieve zero voltage switching for all the primary side switches.

Wei *et al*., (2013) [16] proposed an improved control of rotor side and load side converters with repetitive control in order to compensate the harmonic components in the stator voltage and current of the doubly-fed induction generator (DFIG) when connected with non-linear loads. The non-linear loads results in distorted stator voltage and current with subsequent power quality degradation and electromagnetic torque pulsations of DFIGs. The distorted stator voltage and current are compensated by the proposed hybrid control scheme with repetitive control (RC) based PI controller (PIRC). The harmonic components of different orders and negative sequence component of the stator voltage can be rejected using a single PIRC while most of the other alternative harmonic compensators require separate controllers for damping these components. The PIRC is applied in rotor side converter (RSC) for the purpose of stator voltage compensation and in line side converter (LSC) for stator current compensation, respectively.

Tze-Yee *et al*., (2011) [17] presented an active power factor controller for a PMSM drive to improve the high input current harmonics created from the power diodes as well as the switching of the inverter. The detailed design is analyzed and implemented by a motor drive prototype. This type of utility interface draws excessive peak input currents and hence it produces a high level of harmonics and low input power factor. Due to low power factor, the load efficiency is reduced. In order to meet the harmonics limits, new AC-DC converter designs must employ active power factor correction at the input.

Barathi and Suganthi, (2014) [18] proposed the better speed control of the system was obtained with the help of sliding mode controller (SMC) and the reference value of DC link voltage Vdc which is referred as reference speed. The simulation result performance was also obtained for this proposed work with the reduction in the total harmonic distortion (THD) value due to SMC controller, which is less than the result obtained with conventional (PI) controller. Thus one of the power quality (PQ) problems (reduced THD value) is limited in this proposed system.

Gokilapriya and Karthigayini (2014) [19] presents a bridgeless Cuk rectifier is used for Power factor correction (PFC) for a BLDC motor. Bridgeless Cuk converter has only two semiconductor switches in the current flowing path. During each interval of the switching cycle it result in less conduction losses and an improved thermal management compared to the conventional Cuk PFC rectifier. To achieve almost unity power factor and to reduce the input current stress, the topologies are designed to work in discontinuous conduction mode (DCM). The DCM has additional advantage such as zero-current turn-on in the power switches, zero current turn-off in the output diode. The ac-dc conversion of electric power is usually required for the BLDCM drive, it causes many current harmonics and results in poor power factor at input ac mains. This paper deals with power factor correction of BLDCM with bridgeless Cuk converter. A three phase voltage source inverter is used as an electronic commutator to operate BLDCM.

The Cuk converter offers several advantages in PFC applications, such as easy implementation of transformer isolation, natural protection against inrush current occurring at start or overload current, lower input current ripple, and electro-magnetic interference (EMI) associated with the discontinuous conduction mode (DCM) topology (Huber *et al* 2010) [20] the SEPIC converter, the Cuk converter has both continuous input and out-put currents with a low current ripple. Thus, for applications, which require a low current ripple at the input and output ports of the converter, the Cuk converter seems to be a potential candidate in the basic converter topologies.

3. INFERENCE FROM EXISTING WORKS

From the literature review, it is observed that, various PFC converters have been adopted in different motor applications. The conventional techniques have their own limitations which degrade the overall performance.

A. Limitations of the conventional approaches

Bridge Less buck and boost converter configurations are not suitable for certain high voltage applications due to the requirement of high voltage conversion ratio.

Many topologies of the two-stage PFC converter are reported in the literature which has resulted in lower

ARPN Journal of Engineering and Applied Sciences

efficiency due to higher number of component count for dc link voltage control and PFC operation.

The performance of the DBR with load side motor application for the PFC is analyzed. It is observed from the literature that, higher switching losses are acquired for conventional DBR. The PMBLDC motor drive is fed from a single phase AC supply through a DBR followed by a capacitor at dc link. Due to an uncontrolled charging of the capacitor at dc link, draws a pulsed current. This results in poor power quality (PQ) at AC mains in terms of poor power factor (PF) of the order of 0.728, high Total Harmonic Distortion (THD) of AC mains current at the value of 81.54% and high Crest Factor (CF) of the order of 2.28.

Considering the current conduction modes for PFC, in Continuous Current conduction Mode (CCM), the current in the inductor or the voltage across the intermediate capacitor remains continuous, but it requires the sensing of two voltages (dc link voltage and supply voltage) and input side current for PFC operation, which is not cost-effective. However, Discontinuous Current conduction Mode (DCM) requires a single voltage sensor for dc link voltage control, and inherent PFC is achieved at the AC mains, but at the cost of higher stresses on the PFC converter switch.

The main aim of this research work is to design a novel PFC cuk converter with reduced number of power utility devices. This work also investigates the functionality of the bridgeless cuk converter operated in buck mode with constant DC current and variable DC voltage based on the corresponding speed error. The main objective of this research work is to analyze BLDC with electronic commutation through efficient controlling methods that enable handling output parameters like peak overshoot, peak undershoot, settling time and rise time. The control of the front-end PFC converter generates the PWM pulses for the PFC converter switch 'S' for dc link voltage control with PFC operation at AC mains.

4. COMPARATIVE ANALYSIS

Table-1 shows the comparative analysis of the various converters proposed by several authors. It can be said that the cuk converter provides better results when compared with other converters.

Table-1. Comparative analysis of various converter Topologies.

Author	Techniques	Results
Roshan Kumar (2014)	Soft-switching boost converter	The efficiency, which is about 91% in hard switching, increases to about 96% in the proposed soft-switching converter.
Bikram Das *et al*, (2012)	Boost and Buck Converter	Extra floating switch required which increase complexity and cost. Discontinuous input current in Buck region due to bigger input filter. Filter not required if converter operates from low voltage only
Nesapriya and Rajalaxmi (2013)	Single-phase AC-DC Power Factor Correction (PFC) converters with Fuzzy Logic Controller	It can improve the efficiency of the system about 3-4% when compared with conventional PFC converters
Huber *et al* (2010)	SEPIC converter with the Cuk converter	The results show that all systems track the maximum power point although SEPIC is more stable with less power ripple as compared to Ćuk converter at maximum power output. On the other hand, the advantage of Ćuk converter is the reduction of circuit parameters (capacitor and inductance) as compared to SEPIC converter and hence reduced cost.
Francis and Krishnan, (2014)	Cuk converter	The main advantage of this method is greater efficiency because the switching transistor dissipates little power in the saturated state and the off state compared to the semiconducting state (active region). Other advantages include smaller size and lighter weight and lower heat generation due to higher efficiency

VOL. 10, NO. 7, APRIL 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

5. PERFORMANCE ANALYSIS

The performance of the various converters are analysed and examined using certain metrics like losses (W) due to converter, Efficiency (%) of the converter and power factor.

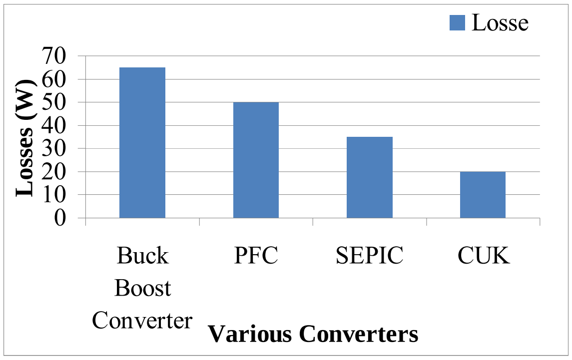

Figure-1. Comparative analysis of the losses of the various converters.

Figure-1 shows the losses with output power for various converters. It can be said that, for Cuk converter the power loss is low when compared with other converters like Buck boost converter, PFC, SEPIC converter etc.

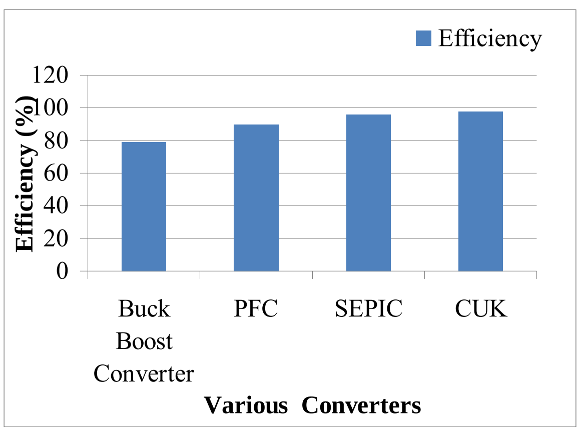

Figure-2. Comparative analysis of the efficiency of the Various converters.

Figure-2 shows the graph between efficiency with output power for various converters. It can be said that the CUK converter provides more efficiency for about 97-98% when compared with other converters like Buck boost converter, PFC, SEPIC converter etc.

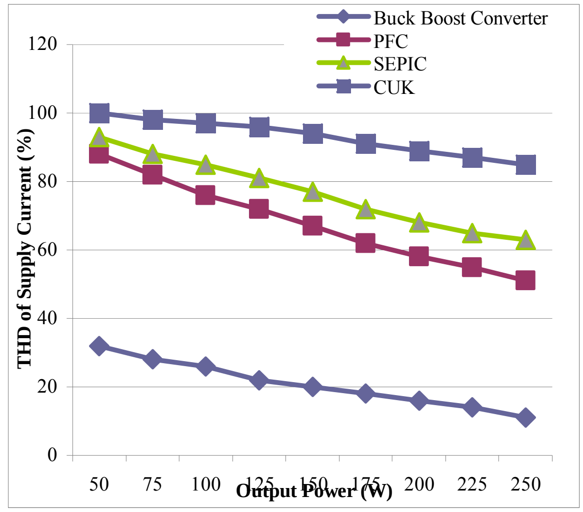

Figure-3. Comparative analysis of the THD of supply current of the various converters.

Figure-3 shows the THD of supply current at ac mains with output power for various converters. It can be said that the CUK converter acquires lower value of total harmonic distortion when compared with other converters like Buck boost converter, PFC, SEPIC converter etc.

6. CONCLUSIONS

The major characteristics to be taken in this research work are converter topology, mode of operation of converter, vector control strategy, electronic commutation and controlling techniques. The existing converter topologies like buck, boost, buck-boost, Cuk and SEPIC had their individual drawbacks in accordance with the specific applications. The most familiar drawback observed in the entire converter topologies is that, it could not maintain high power applications efficiently. As a result, a novel cuk converter is designed with lesser number of power utility devices with efficient controlling techniques which is necessary for high power motor applications.

REFERENCES

[1] M. Veerachary., "Fourth-Order Buck Converter for Maximum Power Point Tracking Applications", IEEE Transactions on Aerospace and Electronic Systems. 2011, vol. 47, no. 2, pp. 896-911.

[2] Kharagpur. "Power Semiconductor Devices". EE IIT. Retrieved. 25 March 2012.

[3] Thirumuru Sravya Saranya, T. Ravi Kumar, S. Sridhar, "A Novel Reference On Driving A Three Phase Brushless DC Motor With A New Matrix Converter", International Journal Of Engineering And Computer Science. 2014, vol.3, no.11, pp. 9273-9278.

[4] C. Senthil kumar, N. Senthil kumar, M. Eswari, “Comparative study of conventional and matrix converter fed brushless dc motor drive”, Electrical Review, ISSN 0033-2097, vol. 89, 2013.

[5] Seyyed.M. Madani and M. M. Shahbazi, “A Soft-Switching hybrid BLDC drive using DC-DC converters”, Electric Machines and drives conferences. 2009, pp. 1290-1294.

[6] Shanmugasundram, R., K. Muhammed Zakariah, and N. Yadaiah, “Low-cost high performance brushless DC motor drive for speed control applications”, In Advances in Recent Technologies in Communication and Computing, 2009. ARTCom'09. IEEE International Conference on. 2009, pp. 456-460.

[7] Roshan Kumar, “A New Soft Switching ZCS and ZVS High Frequency Boost Converter with an HI-Bridge Auxiliary Resonant Circuit to Drive a BLDC Motor”, International Journal of Scientific and Research Publications. vol. 4, no.7, 2014.

[8] Bikram Das, Suvamit Chakraborty, Abanishwar Chakraborti, Prabir Ranjan Kasari “Performance Analysis of BLDC Motor Using Basic Switching Converters” International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, vol. 2, no.1, 2012.

[9] Nesapriya. P., S. Rajalaxmi, ‘Closed Loop Control of Bridgeless Cuk Converter Using Fuzzy Logic Controller for PFC Applications’, World Academy of Science, Engineering and Technology International Journal of Electrical, Robotics, Electronics and Communications Engineering, 2013, vol.7, no.11, pp.1042-1047.

[10] B. Singh, S. Singh, A. Chandra, and K. Al-Haddad, “Comprehensive study of single-phase ac-dc power factor corrected converters with high-frequency isolation”, IEEE Trans. Ind. Informat. 2011, vol. 7, no. 4, pp. 540–556.

[11] Gopalarathnam, T., Toliyat, H.A, “A new topology for unipolar brushless DC motor drive with high power factor”, IEEE Trans. Power Electron., 2003, vol.18, no.6, pp. 1397-1404

[12] Bist, V. and Singh, B., “A Unity Power Factor Bridgeless Isolated-Cuk Converter Fed Brushless-DC Motor Drive”, Industrial Electronics, IEEE Transactions on, no. 99, 2014.

[13] G.Ch. Ramana Kumar, Dr. M. Ram Chandra Rao, “AC/DC Converter with Active Power Factor Correction Applied to DC Motor Drive”, International Journal of Engineering Research and Development, ISSN: 2278-067X. 2012, vol.1, no.11, pp. 58-66.

[14] Tinu Francis, P.Gokula Krishnan, “Embedded based Sensorless Control of PMBLDC Motor With voltage controlled PFC CUK converter for an Air conditioner”, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | p ISSN: 2321-7308.

[15] Hongfei Wu, Kai Sun, Haibing Hu and Yan Xing, “Full-Bridge Three-Port Converters with Wide Input Voltage Range for Renewable Power Systems”, IEEE Transactions on Power Electronics. 2012, vol. 27, no. 9, pp. 3965-3974.

[16] Feng Wei, Vilathgamuwa, D.M. Choi, S.S. Xinan Zhang, “Improved control of rotor- and load-side converters of stand-alone DFIGs under nonlinear loads conditions”, ECCE Asia Downunder (ECCE Asia), 2013, IEEE, pp. 687-691.

[17] Tze-Yee Ho, Mu-Song Chen, Li-Yuan Chen, Lung-Hsian Yang, “The design of a PMSM motor drive with active power factor correction” IEEE conference publications. 2011.

[18] K. Barathi, S. Suganthi, “Speed Control of PMBLDC Motor Using PFC Cuk Converter for Air-Conditioner”, International Journal for Research and Development in Engineering (IJRDE), Special Issue. pp. 120-124

[19] D. Gokilapriya, R. Karthigayini, “A Bridgeless Cuk Converter for Power Factor Correction and Speed Control in BLDC Motor”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, (An ISO 3297: 2007 Certified Organization), vol. 3, no. 5, May 2014.

[20] L. Huber, Y. Jang, and M. Jovanovic, “Performance evaluation of bridgeless PFC boost rectifiers,” IEEE Trans. Power Electron., 2008. vol. 23, no. 3, pp. 1381-1390.