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Analysis of Converters for Single Phase LED Driver with Input Power Factor Correction

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ABSTRACT

Most of the loads in household are inductive in nature and hence have low power factor. When, the power factor is low the current flowing through the system components will be higher. It results in heating and shortens the life of the system. Hence, power factor improvement is necessary. This paper proposes the comparison of bridgeless Single-ended primary-inductance converter (SEPIC) and bridgeless Landsman converter with the input power factor correction for LED drive application. The gating signal for switches in the converters are generated using PWM generator. Bridgeless configuration is used to reduce the conduction loss in the negative half cycle which improves the efficiency of about 1 to 2% for the entire power supply. In this configuration number of conducting diodes is reduced. This proposed work is designed and simulated using MATLAB / Simulink software. The simulated results from the two converters were analyzed for the input power factor correction.

KEYWORDS: *bridgeless SEPIC converter, bridgeless landsman converter, power factor correction*

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I. INTRODUCTION

Light Emitting Diodes (LEDs) are used widely as it reduces power consumption. It also has longer life span [2]. The LED driver plays a major role for its longer life and reduced power consumption. LEDs are ideal for use in applications that are subject to frequent on-off cycling.Most of the source of energy is AC supply, so AC-DC converter must be placed between the input and LED's. To maintain the harmonic contents within limits power factor corrected converter is to be used.

Many converters like buck, boost, buck-boost, cuk converters and their modified forms have been analysed and is in use for LED driver in the market [14]. SEPIC converter is been widely used in all the fields. Bridgeless mode of operation reduces conduction losses so it is used in recent times. In an electric system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. Power-factor correction increases the power factor of a load, improving efficiency for the distribution system to which it is attached.

Comparison of LED drivers is done in the absence ofelectrolytic capacitor [1] with high input power factor. In this buck, boost and bridgeless boost power factor corrector have been analysed. It has two power stages where the switching is complex. The power quality of power factor corrected SEPIC converter is improved [8]-[11]. In this two outer loops are employed, one for voltage control and another for current control. Analysis of Integrated SEPIC–flyback converter is done for power factor correction [3]. Cascaded and optimized structure has been proposed for the power factor correction. The two stage converters are not suitable economically, which adds upon the cost [6]. Bridgeless Landsman converter [12] is a kind of buck-boost converter. It is also used as a power factor corrector. It is used for high brightness application. Bridgeless SEPIC converter is also a kind of buck-boost converter which is used as a power factor corrector. Both the converters are designed such that the inductor operates in discontinuous inductor current mode. LC filter is used in the converters front end to minimize the current in the supply system.

The diode bridge rectifier is ignored; instead the half bridge is used. Using this conduction losses are reduced greatly. In this paper bridgeless mode of SEPIC and Landsman converter is analysed. Proportional and Integral controller is used for the control in closed loop system. It will calculate the error value of the output and the set point.

II. PROPOSED SYSTEM

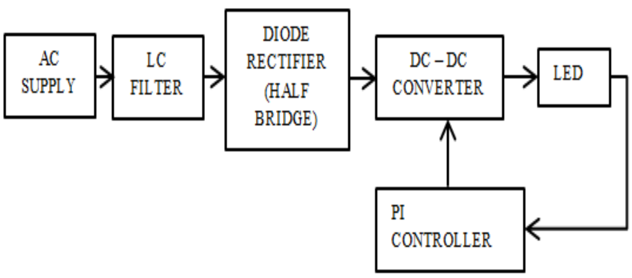

Fig.1. Block diagram of proposed system

Fig.1 illustrates the block diagram of proposed system. AC supply is followed by the LC filter and a diode bridge rectifier (half bridge). Rectifier output is fed to the converter which is a bridgeless SEPIC and LANDSMAN converter. The output voltage of converter is regulated using a PI controller.

III. OPERATION OF CONVERTERS

A. BRIDGELESS SEPIC CONVERTER

Bridgeless SEPIC converter [13] is as shown in Fig.2. It operates in two modes. The two modes are Positive and negative half cycles. In the positive half cycle the switch S_1, L_1, L_3, C_1 are in conduction. In the negative half cycle the switch S_2, L_2, L_4, C_2 are in conduction. The Positive cycle is as shown in Fig.3. In this cycle it has three modes. During the mode 1 when S_1 is turned ON the inductor L_1, L_3 starts charging and capacitor C_1 starts discharging.

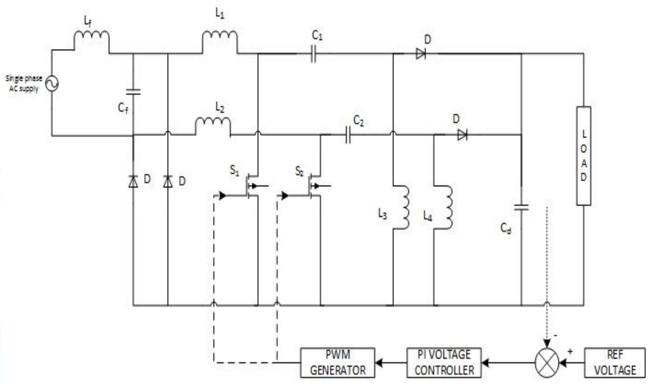

Fig.2. Circuit diagram of bridgeless SEPIC converter

The capacitor C_d supplies the LED. In mode 2 when S_1 is OFF the inductor L_1, L_3 discharges through the diode. In this mode capacitors C_1 and C_d charges. In mode 3 the L_3 discharges completely and L_1 continues to discharge.

The circuit diagram of bridgeless SEPIC converter operating in negative cycle is as shown in Fig.4. It also has three modes of operation same as positive cycle.

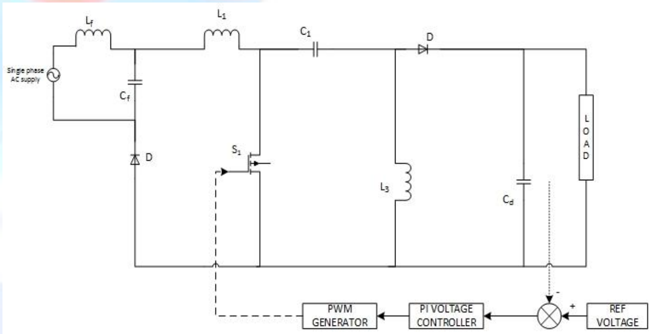

Fig.3. Circuit diagram of bridgeless SEPIC converter operating in positive cycle

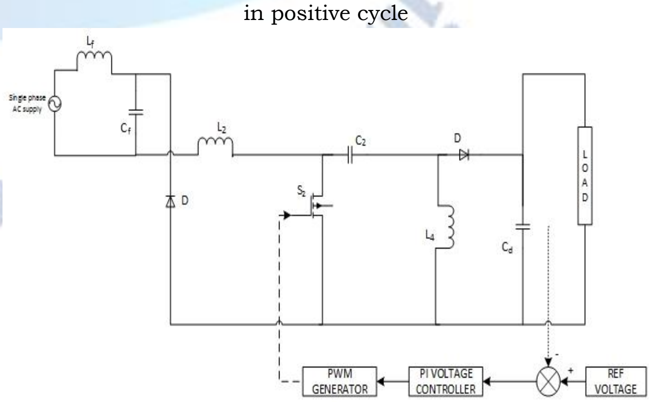

Fig.4. Circuit diagram of bridgeless SEPIC converter operating in negative cycle

B. BRIDGELESS LANDSMAN CONVERTER

Bridgeless Landsman converter [4] is as shown in Fig.5. The mode of operation is split into two. They are positive and negative cycle.

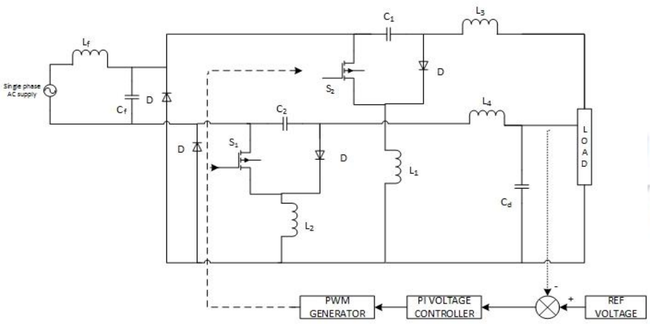

Fig.5. Circuit diagram of bridgeless Landsman converter

In the positive cycle its working is described in three modes. In the first mode when S1 is ON the capacitor C_1 transfers its energy to L_1. The voltage across C_d and inductor current across L_1 starts increasing while the capacitor C_1 discharges through L_3. In the second mode when S_1 is OFF capacitor C_1 and inductor L_3 starts charging. In third mode the inductor L_1 is discharged completely and the inductor L_3 is charging as C_1 is discharging. The negative cycle also works in the same way as positive cycle. In this way the load is supplied continuously by the converter.

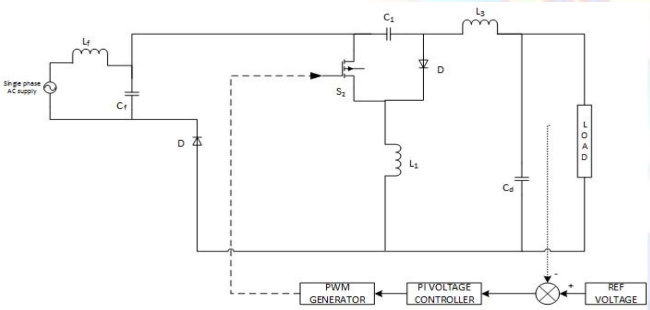

Fig.6. Circuit diagram of bridgeless Landsman converter operating in positive cycle

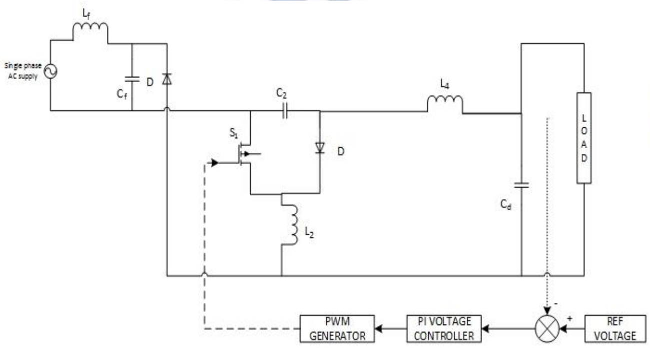

Fig.7. Circuit diagram of bridgeless Landsman converter operating in negative cycle

The positive and negative cycle of bridgeless Landsman converter is as shown in Fig.6. and Fig.7. respectively.

Both the converters output inductors operate in discontinuous conduction mode.

IV. DESIGN OF CONVERTERS

A. DESIGN OF BRIDGELESS SEPIC CONVERTER

The Bridgeless SEPIC Converter design is such that its operation is in Discontinuous conduction mode so that the current flowing in inductors (L_3 and L_4) becomes discontinuous.
The output voltage of a bridgeless SEPIC converter (buck-boost converter) is expressed as

$$V_o = \frac{D}{1-D} V_{in} \qquad (1)$$

The duty ratio, D depends on the voltage, V_{in} and the voltage V_{dc}. The input inductors (L_1 and L_2) are designed for a permitted ripple current of η and expressed as

$$L_1, L_2 = \frac{V_{in}(t)D}{\eta I_{in}(t) f_s}$$

$$L_1, L_2 = \frac{1}{\eta f_s}\left(\frac{V_s^2}{P_i}\right)\left(\frac{V_o}{V_{in}+V_o}\right) \qquad (2)$$

Where, R_{in} is input resistance, f_s is the switching frequency and P_i is the input power. The inductor ripple current should be at the rated condition with current ripple as 30 % of I_{in}.
The output side inductor is designed as

$$L_3, L_4 = \frac{V_o(1-D)}{2 I_{Lo} f_s}$$

$$L_3, L_4 = \left(\frac{V_s^2}{P_i}\right)\frac{V_o}{2V_{in} f_s}\left(\frac{V_o}{V_{in}+V_o}\right) \qquad (3)$$

When the input voltage is minimum the current ripple is maximum in the inductor. And when the input voltage is maximum the value of output inductor is designed. The inductor critical value is designed for maximum and minimum values of output voltages. Therefore, the values of output inductors are chosen such that it is less than the critical Inductance.
The capacitance C_1, C_2 is calculated as

$$C_1, C_2 = \frac{V_o D}{K V_{C_1} f_s R_L}$$

$$C_1, C_2 = \frac{P_i}{K f_s (V_{in}+V_o)^2} \qquad (4)$$

The value of capacitor C_d is calculated by,

$$C_d = \frac{I_d}{2\omega \Delta V_o}$$

$$C_d = \frac{P_i}{2\omega\delta {V_o}^2} \quad (5)$$

The value of capacitor C_d is calculated at maximum and minimum value of output voltages for a permitted ripple voltage (δ) of 3%, Therefore, to ensure a minimum ripple even at lower values of output voltage, the capacitance is selected higher than calculatedC_d.

B. DESIGN OF BRIDGELESS LANDSMAN CONVERTER

The non-isolated power factor corrected Bridgeless Landsman converter drive should operate in discontinuous mode so that inductor currents across L_1, L_2 (I_{L_1,L_2}) are interrupted and the inductor current across L_3, L_4 (I_{L_1,L_2}) and voltage across capacitor C_1 (V_{c1}) persist uninterrupted over one complete cycle.

The output voltage, V_o of a Bridgeless landsman converter (buck-boost converter) is derived as

$$D = \frac{V_o}{V_{in}+V_o} \quad (6)$$

The inductors L_3, L_4 to function in Continuous Conduction Mode for the allowed ripple current is given as

$$L_3, L_4 = \left(\frac{{V_{in}}^2}{P_i}\right)\frac{D}{\Delta_i f_s} \quad (7)$$

For ripple current only 20% input current is allowed. The critical value (L_c) of inductor is calculated as

$$L_{c1}, L_{c2} = \frac{R_{in}V_o D}{2V_{in} f_s} \quad (8)$$

The inductor value ($L_{1,2}$) is chosen lower than its critical value ($Lc_{1,2}$) for its working in discontinuous conduction mode.

The input inductors ($L_{1,\,2}$) are calculated in a range of $1/5^{th}$ of its critical value for assuring its operation in discontinuous conduction mode.

The values of capacitances C_1, C_2 for continuous conduction mode are as

$$C_1, C_2 = \frac{P_i}{K f_s (V_{in} + V_o)^2}$$

Where, K is the ripple voltage across the intermediate capacitor. It is 15 % of V_{c1}.The value of capacitors at maximum input voltage, current and power is denoted as,

$$C_1 C_2 = \frac{P_{max}}{K f_s \left(\sqrt{2}V_{in_{max}} + V_{o_{max}}\right)^2} \quad (9)$$

The value for capacitor C_d is designed as,

$$C_d = \frac{I_o}{2\omega \Delta V_o}$$

$$C_d = \left(\frac{P_{min}}{2\omega \, \Delta {V_{omin}}^2}\right) \quad (10)$$

Where, $P_{min}$is the lowest power which denotes to lowest output voltage for V_{omin} and Δ signify the ample output ripple, and assumed as 3% of output voltage.

C. DESIGN OF LC FILTER

For both the converters LC values are designed to avoid the switching noises as

$$C_{fmax} = \frac{I_m}{\omega_L V_m} \tan(\theta)$$

$$C_{fmax} = \frac{P_{max}\sqrt{2}/V_{in}}{\omega_L \sqrt{2} V_s} \tan(\theta) \quad (11)$$

Where, θ isthe displacement angle of fundamental component of supply voltage and current. So, a lower value of filter capacitance (C_f) derived and given as,

$$C_f < C_{f_{max}}$$

So, filter capacitor value (C_f) is selected less than C_{fmax} .

The value of filter inductance is calculated by considering the input impedance (L_S) of 4-5 % of the base impedance. The required value of inductance is given as,

$$L_f = L_{req} + L_s$$

$$L_{req} = L_f - L_s$$

$$L_{req} = \frac{1}{4\pi^2 {f_c}^2 C_f} - 0.035\left(\frac{1}{\omega_L}\right)\left(\frac{{V_s}^2}{P_{max}}\right) (12)$$

Where, $f_C$is the cut-off frequency. It is chosen such that $f_L < f_C < f_S$. Therefore $f_C$is taken as $f_S/10$.

D. DESIGN VALUES

The design values of the parameters used in the proposed converters are listed in the tables for both the converters. In Table I the design values of bridgeless SEPIC converter is listed. In Table II the design values of Bridgeless Landsman converter is listed.

TABLE I. DESIGN VALUES OF BRIDGELESS SEPIC CONVERTER

S.NO	PARAMETERS	VALUES
1	V_{in}	230 V
2	f_{in}	50 Hz
3	L_f	0.0004 H

4	C_f	1 µF
5	L_1 , L_2	7 µH
6	L_3, L_4	330 µH
7	C_1 , C_2	470 µF
8	C_d	2200 µF
9	Frequency f_s	20 KHz

TABLE II. DESIGN VALUES OF BRIDGELESS LANDSMAN CONVERTER

S.NO	PARAMETERS	VALUES
1	V_{in}	230 V
2	f_{in}	50 Hz
3	L_f	0.00029 H
4	C_f	1 µF
5	L_1 , L_2	70 µH
6	L_3, L_4	3.09 µH
7	C_1 , C_2	440 nF
8	C_d	2200 µF
9	Frequency	20 KHz

The design parameters listed in the tables are used for the simulation of the proposed converter.

V. SIMULATION AND ANALYSIS OF CONVERTERS

The simulation of proposed block diagram is simulated using MATLAB/Simulink. Simulation is done for both the converters using the parameters listed in the Table I and II. The gating signal for the MOSFET is generated through a PWM generator (DC-DC). From the feedback output voltage, error signal is generated and fed to the PI controller to control the output voltage. The output of the converter is fed to the load and performance is analysed. Input power factor is improved through the input LC filter.

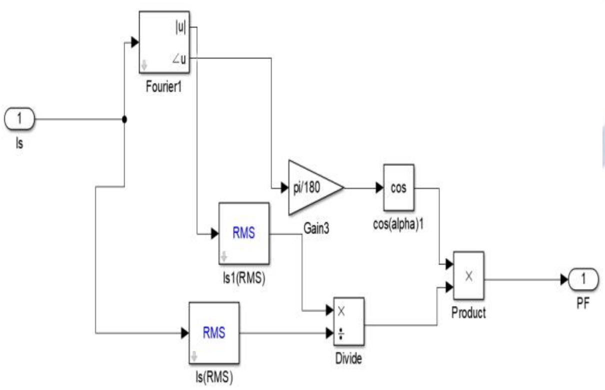

Fig.8. Simulation block diagram to measure input power factor

The simulation block to measure input power factor is as shown in Fig.8. The input power factor is calculated using the equation

$$IPF = \frac{I_{s1}}{I_s} \cos\alpha \qquad (13)$$

The input power factor is observed to be 0.88 for bridgeless SEPIC converter and 0.9385 for bridgeless landsman converter from the simulation.

The output waveform for the simulation of bridgeless SEPIC converter is as shown in Fig.9. From this figure it is inferred that the output voltage is 33.7 V, current is 0.13 A and watts is 4.7 W.

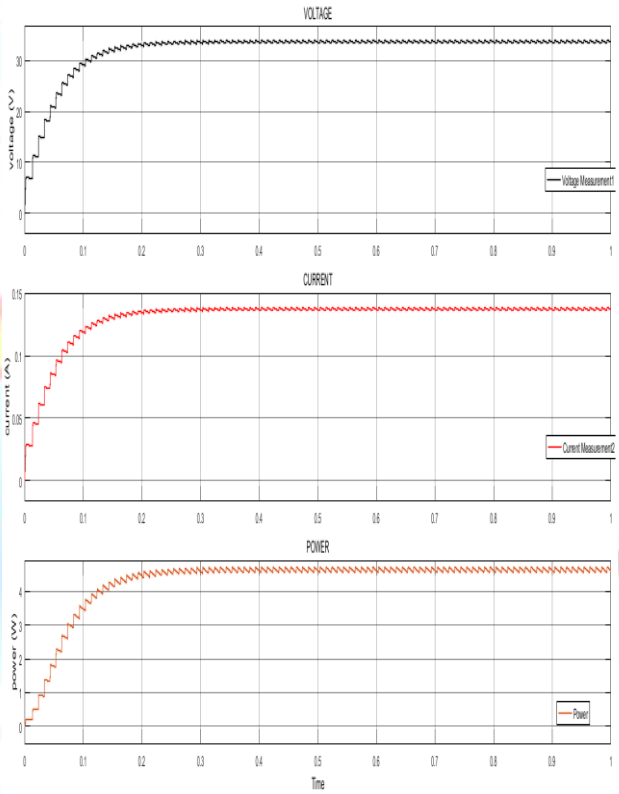

Fig.9. Output waveform of bridgeless SEPIC converter

The output waveform for the simulation of bridgeless landsman converter is as shown in the Fig.10. From this figure we can infer that the output voltage is 30.11 V, current is 0.16 A and watts is 5 W. In the waveforms X axis denotes time (sec) and Y axis denotes voltage (V), Current (A) and Power (W) respectively.

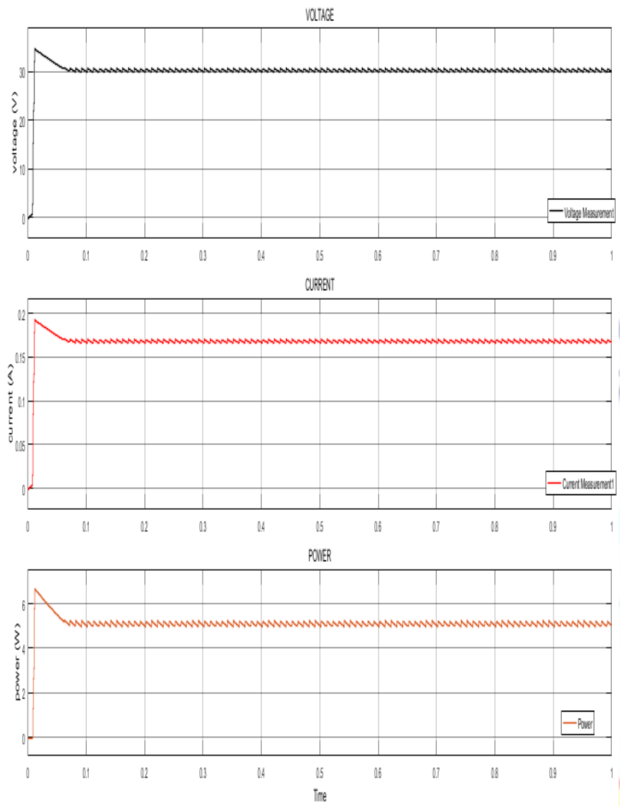

Fig.10. Output waveform of bridgeless SEPIC converter

The analysis of bridgeless SEPIC and Landsman converters are listed in the Table III. From the table we can infer that the power factor of landsman converter is better than that of SEPIC converter.

TABLE III. PERFORMANCE OF THE CONVERTERS

PARAMETERS	LANDSMAN CONVERTER	SEPIC CONVERTER
INPUT POWER FACTOR	0.9385	0.88
OUTPUT VOLTAGE	30.11 V	33.7 V
OUTPUT CURRENT	0.16 A	0.1376 A
OUTPUT POWER	5 W	4.7 W

VI. CONCLUSION

The simulation of bridgeless SEPIC and Landsman converter for single phase LED driver are performed in MATLAB/Simulink. The results are analysed and tabulated. It is inferred that the input power factor of bridgeless SEPIC converter is 0.88 and for bridgeless Landsman converter is 0.93. And the output power of bridgeless SEPIC converter is 4.7 W and for bridgeless Landsman converter is 5 W. From this analysis the bridgeless landsman converter has better input power factor and output power than bridgeless SEPIC converter. Hence bridgeless Landsman converter configuration works better than bridgeless SEPIC converter for single phase LED driver application. The prototype of the landsman converter for LED drive application can be implemented.

REFERENCES

[1] Hao Wu,Siu-Chung Wong, Chi K. Tse,S. Y. Ron Hui and Qianhong Chen "Single-Phase LED Drivers with Minimal Power Processing, Constant Output Current, Input Power Factor Correction, and without Electrolytic Capacitor",vol. 33, no. 7, pp. 6159-6170, 2017.

[2] P. S. Almeida, D. Camponogara, M. D. Costa, H. Braga, and J. M.Alonso, "Matching LED and driver life spans: a review of different techniques", IEEE Industrial Electron. Magazine, vol. 9, no. 2, pp. 36–47, June 2015.

[3] B. Poorali and E. Adib, "Analysis of the integrated SEPIC-flyback converter as a single-stage single-switch power-factor-correction LED driver", IEEE Trans. Industrial Electron., vol. 63, no. 6, pp. 3562–3570, June 2016.

[4] Singh, Praveen Kumar, Bhim Singh, Vashist Bist, Kamal Al-Haddad, and Ambrish Chandra. "BLDC motor drive based on bridgeless landsman PFC converter with single sensor and reduced stress on power devices." IEEE Transactions on Industry Applications 54, no. 1 (2017): 625-635.

[5] Singh, Praveen Kumar, Bhim Singh, and Vashist Bist. "Brushless DC motor drive with power factor regulation using Landsman converter." IET Power Electronics 9, no. 5 (2016): 900-910.

[6] Camponogara, Douglas, Guilherme F. Ferreira, Alexandre Campos, Marco A. Dalla Costa, and Jorge Garcia. "Offline LED driver for street lighting with an optimized cascade structure." IEEE Transactions on Industry Applications 49, no. 6 (2013): 2437-2443.

[7] Bertoldi, Bruno, Marcio Moura Bridon Junior, Matheus Schramm Dall'Asta, Marcos Paulo Mocellini, Greidanus Mateo Daniel Roig, André Luis Kirsten, and Marcelo Lobo Heldwein. "A Non-Ideal SEPIC DCM Modeling for LED Lighting Applications." In 2018 IEEE 4th Southern Power Electronics Conference (SPEC), pp. 1-7. IEEE, 2018.

[8] Sukanya, S., K. Gayathri, and R. Thenmozhi. "A power quality improved isolated bridgeless sepic converter for LED lamp." In 2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT), pp. 1-7. IEEE, 2017.

[9] Yadav, Avdhesh, Rupendra Kumar Pachauri, and Yogesh K. Chauhan. "Power quality improvement using PFC SEPIC converter for LED bulb adaptable for universal input voltage." In 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), pp. 1-6. IEEE, 2016.

[10] Ali, Mokhtar, Mohamed Orabi, Mahrous E. Ahmed, and Abdelali El-Aroudi. "A single stage SEPIC PFC converter for LED street lighting applications." In 2010 IEEE International Conference on Power and Energy, pp. 501-506. IEEE, 2010.

[11] Aman Jha, Bhim singh, 2016, "SEPIC PFC converter for LED driver", IEEE international conference on power electronics, Intelligent Control and Energy systems.

[12] Jha, Aman, and Bhim Singh. "Modified bridgeless landsman PFC converter for LED driver." In 2016 7th India International Conference on Power Electronics (IICPE), pp. 1-6. IEEE, 2016.

[13] Bist, Vashist, Bhim Singh, Ambrish Chandra, and Kamal Al-Haddad. "An adjustable speed PFC bridgeless-SEPIC fed brushless DC motor drive." In 2015 IEEE Energy

Conversion Congress and Exposition (ECCE), pp. 4886-4893. IEEE, 2015.

[14] Singh, Bhim, Ashish Shrivastava, Ambrish Chandra, and Kamal Al-Haddad. "A single stage optocoupler-less buck-boost PFC driver for LED lamp at universal AC mains." In 2013 IEEE Industry Applications Society Annual Meeting, pp. 1-6. IEEE, 2013.

[15] Shrivastava, Ashish, and Bhim Singh. "Improved power quality converter based electronic ballast with high power factor." In 2012 IEEE 5th India International Conference on Power Electronics (IICPE), pp. 1-6. IEEE, 2012.