Comparative Analysis Of Improved Quality Three Phase AC/DC Converters Based On Flyback And Cuk Topologies

V.Sree Vidhya[1], M.Gopi Chand Naik[2], D.Deepak Chowdhary[3]
[1]ME Scholar (Power Electronics and Drives), Department of Electrical Engineering, Andhra University , Visakhapatnam-530003,Andhra Pradesh, India.
[2]Assistant Professor, Department of Electrical Engineering, ,Andhra University, Visakhapatnam-530003 . Andhra Pradesh, India.
[3]Head of the Department, Electrical Engineering,Dr. L.Bullaya College of Engineering For Women, Visakhapatnam, Andhra Pradesh ,India.

Abstract: This paper presents the comparative analysis of improved quality three phase AC/DC Flyback and Cuk converters, using SIMULINK. Comparisons of three phase converters is done to identify the converters with low cost/high efficiency for the system by reducing number of stages and improve quality in terms of power factor correction, reduced THD at input ac mains and regulated dc output. The primary market target of the converter is within the telecommunications industry where it supplies high-quality dc power to the telecom loads and performs high-capacity battery charging while providing zero harmonic emission and unity power factor to the utility grid. The main design objective is to produce the lowest cost within a small-size system The study includes the use of optimum number of cells to be interleaved and the associated phase shifts among the cells are determined on the design of a isolated flyback transformer with the lowest leakage inductance and selection of components providing the lowest parasistic effects critical for obtaining high efficiency and good performance.. The performance of the three phase AC/DC Flyback and Cuk converters are verified at 220 Vrms phase voltage, 8400W and 750 W output power respectively through MATLAB/simulation model and a good consistency is achieved.

Keywords: Improved Quality Converters, PWM Generator, Three-Phase AC/DC Flyback and Cuk Converters, Total Harmonic Distortion (THD), Power Factor Correction.

I.INTRODUCTION

AC/DC power converters are broadly used in various applications like power supplies, dc motor drives, front-end converters in adjustable-speed ac drives, HVDC transmission, SMPS, in process technology like welding, power supplies for telecommunications systems, aerospace, military environment and so on. Harmonic pollution and low power factor in power system caused by power converters have been a great concern. To overcome these problems several converters and control schemes have been proposed in recent years. The harmonics drawn from the utility lines due to distorted current waveforms and the low power factor caused by these currents are important power-quality problems [1]–[4]. The common approach for the solution of these problems in high-power applications is to use two-stage power conversion schemes. The two-stage schemes employ a power-factor correction stage where harmonic currents are eliminated and another cascaded stage such as a dc–dc converter for generating regulated output with fast dynamic response and isolation. However, the cascaded converters increase the complexity of the system, and hence, the cost and the size of the product. For this reason, major research has been carried out for the development of less complex single-stage systems that provide the same performance as their two-stage counterparts [5]-[15].A new type of AC/DC converters is specifically known as Power Factor Correction Converters (PFCs), Switched Mode Rectifiers (SMRs), PWM Converters, Improved Power Quality Converters IPQCs), and High Power Factor Converters (HPFCs).They are included as an inherent part of excellent power quality at the line-side and load-side, higher efficiency, and reduced size. The power quality issues created by the use of conventional AC/DC converters are elegantly addressed by improved quality converters. The output voltage is regulated even under the fluctuations of source voltage and sudden load changes. The PWM switching pattern controls the switching of the power devices for input current wave shaping so that it becomes almost harmonic-pollution free and in phase with the source voltage, thus producing a nearly sinusoidal supply current at unity power factor. These converters provide improved quality not only at input ac mains but also at dc output for better design of overall equipment. Interleaving allows reducing the current peaks since the power is shared among the cells, and at the same time it reduces the discontinuity in the current waveform before and after the interleaving points, because the phase shifted cells draw currents at different intervals of the switching period. Improved quality converters are classified into categories on the basis of converter circuit topologies such as buck, boost, buck–boost, Flyback and Cuk, unidirectional and bidirectional dc output voltage, current and power flow. Three-phase quality improvement converters can be classified on the basis of :

- Converter topology as boost, buck, buck–boost, Flyback and Cuk converters with unidirectional and bi-directional power flow.

- Type of converter used as unidirectional and bi-directional converters

II. IMPROVED QUALITY THREE PHASE AC/DC CONVERTERS

Conventionally, diode rectifiers or thyristor bridge converters were employed to synthesize dc voltage from the ac utility. These rectifiers pollute the utility with low-order harmonics, which are difficult to filter. Pulse width modulation (PWM) converters are employed to overcome this problem. These converters shift the frequency of the dominant harmonics to a higher value, so that they can be easily filtered by employing a small passive filter. The PWM converter draws a near-sinusoidal input current while providing a regulated output dc voltage.

A. Advantages of Flyback or Cuk Topology are:

- High efficiency
- High power density
- Inherent power quality improvement at input and output.

Hence these type of converters not only provide regulated DC output voltage but also maintain unity power factor and low THD on current at the input. These type of ac-dc converters with various topologies have found wide spread use in various applications.The ac-dc converter topologies are considered based on single stage conversion with the use of optimum number of cells to be interleaved and associated phase shifts among the cells are determined and listed below.

(1) Flyback Converter (2) Cuk Converter

Three phase improved quality converter have gained considerable attention due to the increasing demand to power quality. These types of converters are widely used nowadays as a replacement of a conventional diode rectifier to provide:

• Unity power factor
• Reduced THD at ac mains
•Constant-regulated dc output voltage even under fluctuations of ac voltage and dc load.

B. Operational principles of the converter

The operating principles of both the converters are discussed below:

(1) Flyback Converter

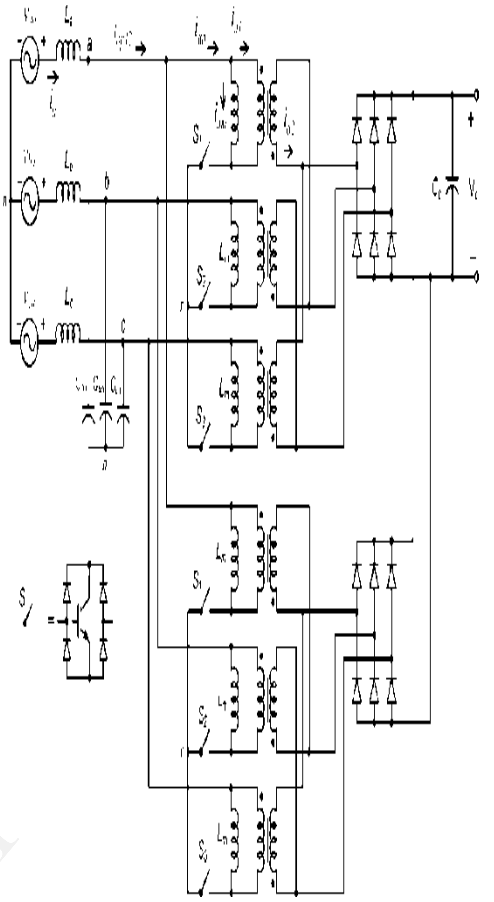


Fig.1.Circuit topology of the proposed two-cell interleaved converter.

The energy conversion in Flyback-based converters is performed indirectly using the magnetic components, which are the magnetizing inductance (L_m) of the flyback transformers shown in Fig. 1. The three controllable switches placed in series with the primary of transformers are operated simultaneously using the same gate pulse. Because of the DCM operation, every time the switches are turned on, the primary winding current and also the flux in the core starts from zero and increases almost linearly to a maximum. During this mode, energy is stored in the magnetizing inductance of the flyback transformer, and no current flows to the secondary side due to the diodes at the output, during this time the load power is supplied by the

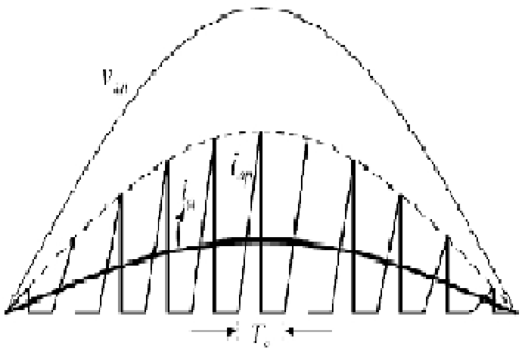


Fig. 2. Theoretical waveforms of the input voltage (*van*), the flyback transformer primary winding current (*iap*), and its instantaneous average (ia)

output capacitor C_O .The energy transfer to the output occurs during the off time of the switches, and no energy is drawn from the source. The energy stored in the magnetizing inductances of each phase is transferred to the output through the flyback transformer secondary windings and the three-phase rectifiers. The ripple at the output voltage caused by the rectified secondary currents is smoothed out by the capacitor C_O. The average output voltage is regulated by controlling the duty ratio of switches (pulse width modulation (PWM) method) over a fixed switching period. While the switch remains off, the dc output voltage reflects across the primary winding as negative voltage and resets the flux in the core. The same input ac voltage is applied to every cell of interleaved converter. Since the cells are constructed using identical components and the same control signal is used to produce the PWM pulses, the power sharing of the cells is achieved. Operation in DCM mode offers many advantages such as elimination of turn-ON switching losses and the losses associated with the reverse recovery of the diodes, elimination of half-plane zero in the feedback loop that allows a robust and stable control, and lastly, the fast dynamic response.

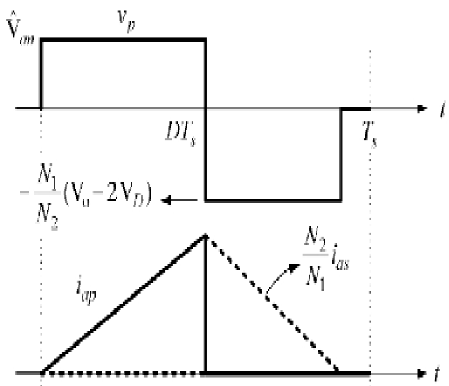


Fig. 3. Waveforms of the transformer primary voltage *vp* , the transformer primary current *iap* , and the secondary current *ias* referred to the primary side.

This figure shows the primary current *i*ap and its average _iap _ Ts over one switching period. The average of the primary current when *v*an is at its peak gives the magnitude of the sinusoidal current drawn from the utility line, which is I_a

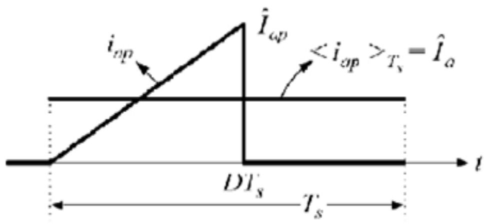


Fig.4. Transformer primary current *iap* over a switching cycle and its cycle based

Disadvantages

- The DCM operation is associated with a higher voltage or current stress.
- High switching losses.

(2) Cuk Converter:

An isolated dc–dc Cuk converter is shown in Fig.5 .The input section resembles that of a boost converter, while the out- put section is similar to a buck stage. It offers either step-up or step-down output voltage with respect to the input, producing a negative output voltage from a positive input voltage. The magnetizing inductance of Cuk converter does not carry a dc current component, so that the transformer can be fully utilized. It is interesting to note that, with a proper choice of the inductances, the line current of Cuk converter remains continuous even if one or both of the inductors operate in the discontinuous conduction mode, and thus, input filter requirement can be reduced. Advantages can be gained by magnetically coupling the two inductors.In the continuous conduction mode (CCM) of operation, the voltage waveforms of the input inductor, output inductor, and transformer windings are proportional in magnitude, and have the same frequency and phase shift. Therefore, it is possible to integrate these three elements in one magnetic structure, with zero current ripples in both input and output inductors. Many additional benefits are achieved from the magnetic integration, such as high power density, low cost, lower operating frequency, low noise and EMI, high efficiency, and small-size filtering component at the input and output side. The active rectifier front end of a dc distributed power system (DPS) has been attracting increased attention due to incessantly growing power quality concerns Modular design of each unit in the DPS is good for maintainability. Due to its high efficiency, good current quality, and low EMI emissions a three-phase PWM rectifier is normally applied for high-power applications. However, this type of three-phase PFC converter has more component counts and a complicated controller design that causes poor reliability.

A three-phase converter using single- phase single-switch modular rectifier topology has the merits of simple control and few components. They are becoming popular for low- voltage or medium-power applications. A three-phase converter using three modified single-phase single-switch boost rectifier modules was proposed for high- power and high-voltage applications. Normally, a single-phase boost PFC converter converts an ac voltage to a dc voltage, which is higher than the ac peak value (for an ac three-phase 380 V supply, the dc output voltage may be higher than 588 V_{dc}). Compared to the conventional three-phase PWM rectifier, this type of three-phase PFC converter features a simple and robust configuration. The converter can achieve almost unity power factor, nearly sinusoidal input current, and adjustable output voltage. The two-stage operation would lead to reduced efficiency, and increased size and cost of magnetic, filtering components. To avoid the problem arising from the traditional two-stage conversion approach, a single-stage three-phase ac–dc converter, as shown in Fig. 5, is examined. It consists of three modules connected in parallel. Each module comprises a diode rectifier and a Cuk converter with electrical isolation. The performance of the Cuk converter suggests that this is the best topology. The Cuk converter also offers greater flexibility in the configuration that can be implemented as isolation is easily incorporated.

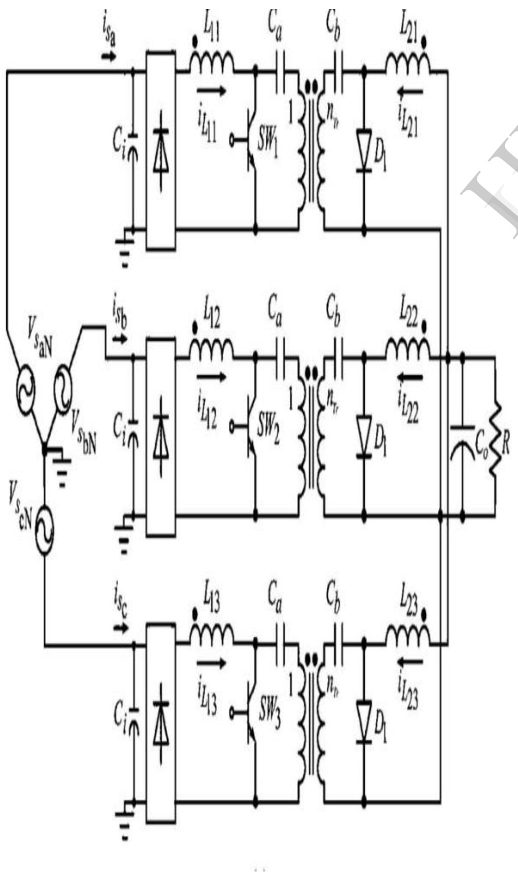


Fig.5 Power circuit of the modular three-phase ac-to-dc converter using CUK rectifier.

In this paper, the implementation and control of the three-phase AC-to-DC converter using three single -phase isolated Cuk rectifier with nearly unity power factor and fast dynamic transient response for telecommunication systems is presented under the continuous-conduction-mode (CCM) of operation. The objective of the proposed scheme is to overcome the disadvantages of the three conversion stages in cascade (PFC stage, dc-to-ac stage, and ac –to-dc stage) to simplify the design procedure of the dc bus voltage regulator, PFC, and inductor current sharing, and to improve the dynamic response. It is used to obtain the inductor current compensator, thus resulting in the output impedance and audio susceptibility becoming zero, i.e., the output voltage of the converter presented in this paper is independent of the variations of the dc load current and the utility voltage. This control strategy has high dynamic features, and can achieve a fast dynamic transient response by action of the inductor current compensator. The deduction of the proposed inductor current compensator is also quite easy, but the effect is sensible. Its main features include: the proposed system's modularity, simple control strategy, and design; the second-order harmonic current component in the output capacitor is cancelled, and this significantly reduces capacitor heating, improves its operating life, and could minimize a dc bus capacitor.

According to the application need best topology is used. Switch mode improved quality AC/DC converters with high efficiency and power density are being used as front end rectifiers for various application.

Simulation Parameters:

Table I: Main specifications of the Flyback converter with 3-cell interleaved

Parameters	**Range**
Input phase voltage	220V
Input Frequency	50 Hz
THD of input current	< 5 %
Duty ratio	30.77 to 70%
Output voltage	46 to 56 volts
Maximum power out put	8400 Watts
Power factor	>0.99
Efficiency	>85%
Switching Frequency	20 KHz
Magnetizing Inductance(L_m)	150μH
Output Capacitance(C_o)	2870μF
Turns ratio,n	9

III. SIMULATION RESULTS AND ANALYSIS

A.*Simulation study of three-phase AC/DC Flyback and Cuk converters has been done through* ***MATLAB/SIMULINK*** *software*.

(1) Flyback Converter

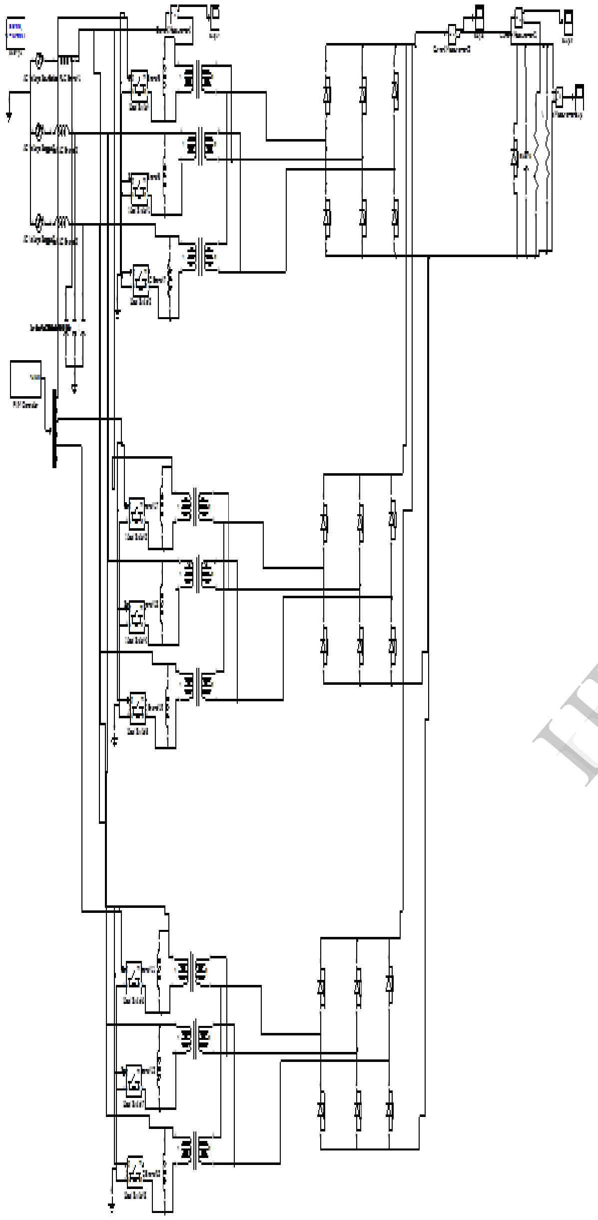


Fig 6. Simulation circuit diagram of Flyback converter with 3-cell interleaved

(2) Cuk Converter

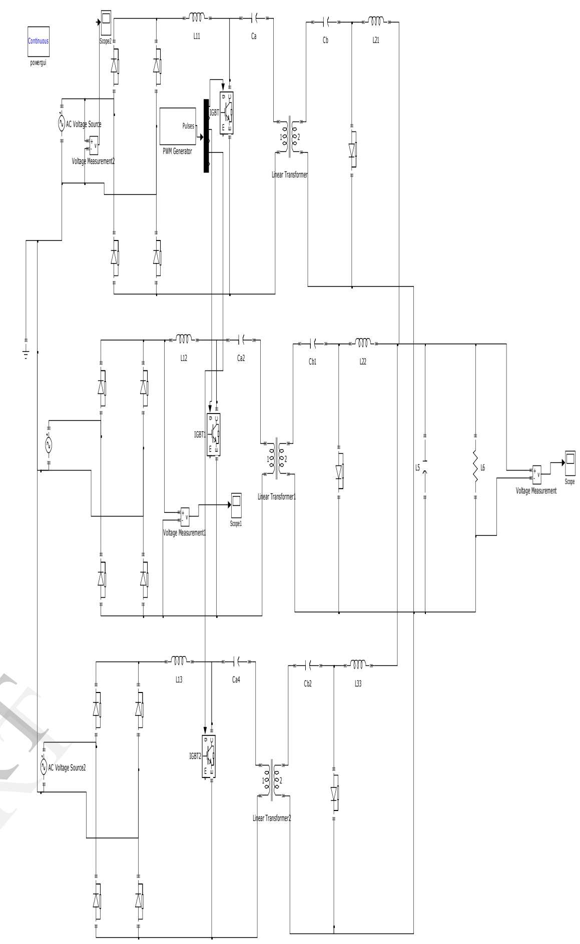


Fig 7. Simulation circuit diagram of Cuk converter

Table II: Main specification of the Cuk converter:

Characteristic	Range
Input phase Voltage	220 V
Input Frequency	50 Hz
Switching Frequency	20 KHz
Total Output Power	750 W
Output Voltage	-48 V
L_{11},L_{12},L_{13}	5.069mH,5.068mH, 5.066mH
L_{21}, L_{22}, L_{23}	1.066mH,1.086mH, 1.044mH
C_a, C_b, C_o	0.68 µF, 13,600 µF
n_{Tr}	0.5

ISSN: 2278-0181
Vol. 2 Issue 1, January- 2013

B. Simulation Results:

B.1 Power Factor Analysis for Input side

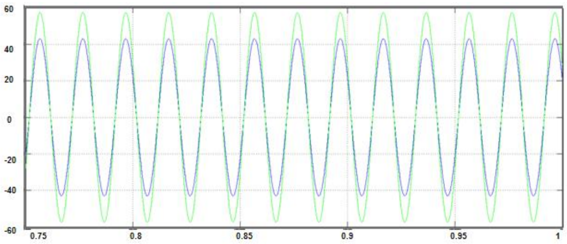


Fig.8 Flyback converter with 3-cell interleaved

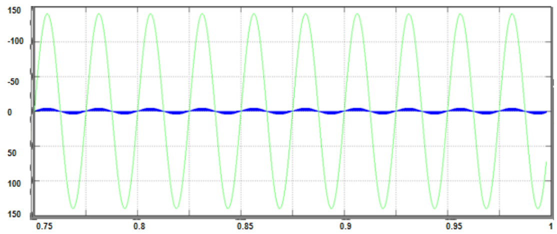


Fig.9 Cuk converter

The three-cell interleaving provides significant decrease in the peaks of input current .It also provides a factor of three increase in ripple frequency and substantial reduction in the discontinuity of the waveform. Fig 8 and Fig 9 shows that the Flyback converter in DCM shows better current-shaping properties when compared with the Cuk converter. An active power-factor correction circuit can process either total input power or just a portion of the input power. So the power factor is always higher than 0.99 in DCM.

B.2 Total Harmonic Distortion (THD) Analysis

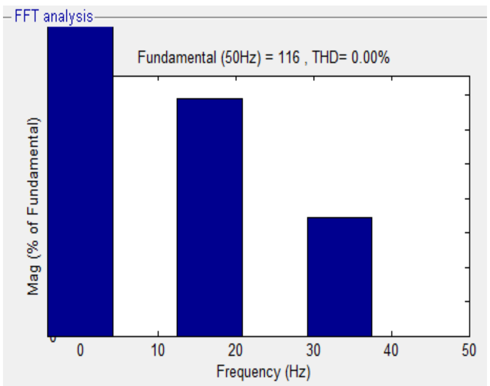


Fig.10 Flyback converter with 3-cell interleaved

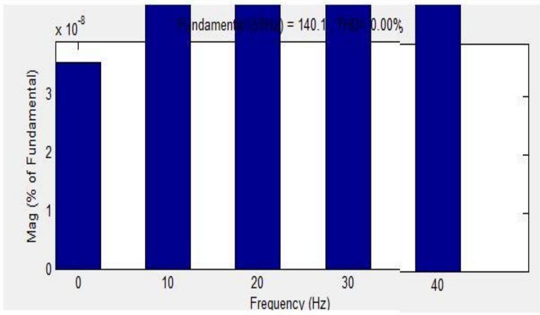
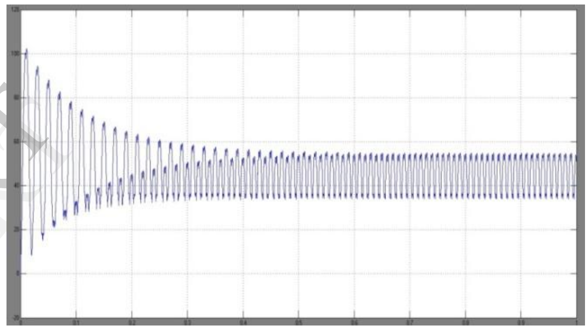


Fig.11. Cuk converter

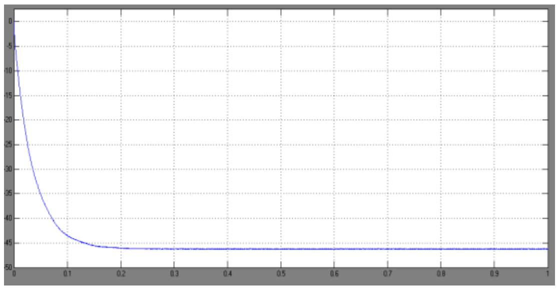
From Fig.10 and Fig.11shows the THD at the input current is much lower than the 5% requirement for both the converters.

B.3 Output Voltage Waveforms



Time(secs)

Fig.12. Flyback converter with 3-cell interleaved



Time(secs)

Fig 13. Cuk converter

The dynamic response of the converter was also evaluated and controller parameters were optimized to obtain a fast transient voltage regulation. Fig. 12 and Fig.13 shows the dynamic response of the converter output voltage during a voltage regulation test.

C. Comparative Analysis of Flyback and Cuk converters

Characteristic	Flyback	Cuk
Output voltage	55V	-48 V
Power output	8400 W	750 W
THD	around 1%	0.00%
Operating mode	discontinuous	continuous
Power Factor	unity	Nearly unity
Efficiency	87%	88%

Hence, two topologies are discussed. According to the application need best topology is used and Achieving high overall efficiency as single-stage unity-power-factor converter is acceptable for most applications.

IV. CONCLUSION

This paper has presented the comparative analysis of three phase improved quality AC/DC converters based on Flyback and Cuk topologies with unity power factor and fast dynamic transient response based on power balance control technique. Additionally, this study presented the realization of extremely low leakage high-power Flyback transformer and the significant benefit of interleaving method. The proposed approach offers the following advantages: simple control and fast dynamic response, low cost, nearly zero harmonic emission to the utility lines. The results obtained are: an output power and THD are measured. Therefore the use of these converters results in equipment behaving as a linear load at three-phase ac mains and solves the quality improvement problems due to ac/dc converters and are gaining popularity in a variety of applications ranging from low to high power levels due to their improved power quality both at the input as well as the output terminals.

REFERENCES

[1] B. Singh, B.N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, D.P. Kothari, ―A Review of Three-phase Improved Power Quality AC/DC Converters‖, IEEE Trans. Ind. Electron 51, 2004.

[2] Abdul Hamid Bhat , Pramod Agarwal, ―Three-phase, Power Quality Improvement AC/DC Converter ‖, Electric Power Systems Research 78 ,2008

[3] Abdul Hamid Bhat and Pramod Agarwal, ―Improved Power Quality AC/DC Converters‖, EPSR 79 ,2009

[4] A. R. Prasad, Phoivos D. Ziogas, and Stefanos Manias, ―An Active Power Factor Correction Technique for Three-phase Diode Rectifiers‖, IEEE transactions on Power Electronics, vol. 6 (1991)

[5] *IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems*, 1992, IEEE Standard 519, 1992.

[6] *Limits for Harmonic Current Emissions*, 1995, IEC 1000-3-2, 1995.

[7] A. R. Prasad, P. D. Ziogas, and S. Manias, "An active power factor correction technique for three phase diode rectifiers," *IEEE Trans. Power Electron.*, vol. 6, no. 1, pp. 83–92, Jan. 1991.

[8] R. Erickson, M. Madigan, and S. Singer, "Design of a simple high-power factor rectifier based on the flyback converter," in *Proc. IEEE Appl. Power Electron. Conf. Proc.*, 1990, pp. 792–801

[9] H.-Y. Li, H.-C. Chen, and L.-K. Chang, "Analysis and design of a single stage parallelAC-to-DC converter," *IEEE Trans. Power Electron.*, vol. 24, no. 12, pp. 2989–3002, Dec. 2009.

[10] U. Kamnarn and V. Chunkag, "Analysis and design of a modular three phase AC-to-DC converter using CUK rectifier module with nearly unity power factor and fast dynamic response," *IEEE Trans. Power Electron.*, vol. 24, no. 8, pp. 2000–2012, Aug. 2009.

[11] R. L. Alves and I. Barbi, "Analysis and implementation of a hybrid high power- factor three-phase unidirectional rectifier," *IEEE Trans. Power Electron.*, vol. 24, no. 3, pp. 632–640, Mar. 2009.

[12] L.-S. Yang, T.-J. Liang, and J.-F. Chen, "Analysis and design of a novel Three - phase ac–dc buck–boost converter," *IEEE Trans. Power Electron*, vol. 23, no. 2, pp. 707–714, Mar. 2008.

[13] D. D.-C. Lu, H. H.-C. Iu, and V. Pjevalica, "A single-stage AC/DC converter with high power factor, regulated bus voltage, and output voltage," *IEEE Trans. Power Electron.*, vol. 23, no. 1, pp. 218–228, Jan. 2008.

[14] H. M. Suryawanshi, M. R. Ramteke, K. L. Thakre, and V. B. Borghate, Unity power -factor operation of three-phase ac–dc soft switched converter based on boost active clamp topology in modular approach," *IEEE Trans. Power Electron.*, vol. 23, no. 1, pp. 229–236, Jan. 2006.

[15] Bunyamin Tamyurek and David A.Torrey,"A Three-Phase Unity Power Factor Single-Stage ac-dc based on anInterleavedFlyback Topology",*IEEE Transactions on Power Electron*, vol. 26, no. 1,pp.308-318, Jan 2011.