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Maintaining power quality standards for personal computers using Zeta Converters

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Abstract— **Nowadays, computer loads are essential commodity of any society's industrial, commercial and residential sectors which needs quality power for their better performance. This paper discusses the significance of power quality for personal computers and different methods used to improve power quality. The role of Zeta converter in enhancing power quality is highlighted.**

***Keywords*— Computers, power quality, harmonic distortion, Zeta converter**

I. INTRODUCTION

Computers should have a reliable power supply all the time as they may crash due to voltage sags in power supply [1]. This necessitated the use of Uninterruptible Power Supplies (UPS) for computers. Fig 1 shows the voltage and current waveforms of a computer workstation which doesnot use any power conditioners.

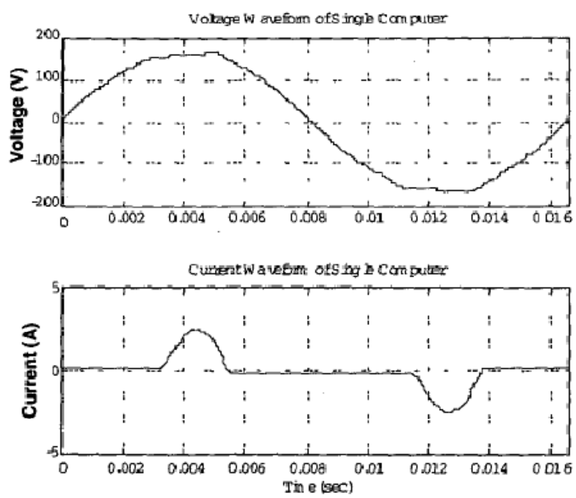

Fig 1 Voltage and current waveforms of a single computer workstation.

It can be seen from the figure that the current waveform is highly distorted and Total Harmonic Distortion (THD) current waveform is 110% [2]. According to Institute of Electrical and Electronics Engineers (IEEE) Standards the THD should be lower than 5% for voltage and current waveforms.

With the development of switching devices, the Switched Mode Power Supplies (SMPS) are becoming more popular. SMPS are used for powering up different parts in a personal computer (PC) by developing multiple DC voltages from a singlephase AC voltage from the power grid. Normally, a Diode Bridge Rectifier (DBR) followed by a filter capacitor is used at the front end of these SMPS. Various topologies of AC-DC converters are used in SMPS to improve power quality for personal computers.

II. DEFINITION OF POWER QUALITY

The term power quality describes multitude of issues that are found in any electrical power system and is a subjective term. The concept of good and bad power depends on the end user. If a piece of equipment functions satisfactorily, the user feels that the power is good. Various sources use the term, power quality with different meaning. It is used synonymously with supply reliability, service quality, voltage quality, current quality, quality of supply, and quality of consumption [3].

Power quality which is vaguely named as reliability is defined in the 'Authoritative Dictionary of IEEE Standard Terms' as "The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment".

Main sources of harmonics in power system are;

- Industrial nonlinear loads such as power electronic equipment, for example, drives, rectifiers,, inverters, arc furnace, welding machines and
- Residential loads with SMPS such as television sets and computers.

Some detrimental effects of harmonics are;

- Maloperation of control devices, relays etc.
- Additional losses in capacitors and transformers.
- Telephone interference.
- Causing parallel and series resonance frequencies (due to powerfactor correction capacitors), resulting in voltage amplification even at a remote location from the distorting load.

III. POWER QUALITTY STANDARDS

Power quality being a worldwide issue, keeping a common power quality related standards all over the world is a never ending task. Power quality standards are formal agreements between industry, users and government as to the proper procedure to generate, test, measure, manufacture and consume electric power [3]. Standards and guidelines set to keep disturbances to user equipment within permissible limits, to provide uniform terminology and test procedures for power quality problems and to provide a common basis of reference.

Some of the commonly used guidelines, recommendations, and standards are set by ;

- Institute of Electrical and Electronic Engineering (IEEE)
- International Electrotechnical Commission (IEC)

A. *IEEE - 519*

IEEE 519-1992, "Recommended Practices and Requirements for Harmonic Control in Electric Power Systems", establishes limits on harmonic currents and voltages at the Point Of Common Coupling (PCC), or point of metering. The limits of IEEE 519 are intended to:

1) Assure that the electric utility can deliver relatively clean power to all of its customers;

2) Assure that the electric utility can protect its electrical equipment from overheating, loss of life from excessive harmonic currents, and excessive voltage stress due to excessive harmonic voltage.

IEEE 519 lists the limits for harmonic distortion at the Point of Common Coupling (PCC) or metering point with the utility. The voltage distortion limits are 3% for individual harmonics and THD is limited to 5% for both current and voltage harmonic distortions [5].

B. *IEC 61000-3-2 and IEC 61000-3-4 (formerly 1000-3-2 and 1000-3-4)*

IEC 61000 series of standards are the most commonly used reference for power quality in Europe.

- IEC 61000-3-2 (1995-03)

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It specifies limits for harmonic current emissions applicable to electrical and electronic equipment having an input current up to and including 16 A per phase, and intended to be connected to public low voltage distribution systems.

- IEC/TS 61000- 3-4 (1998-10)

It specifies limits for electrical and electronic equipment with a rated input current exceeding 16 A per phase and intended to be connected to public low voltage AC distribution systems. These recommendations specify the information required to enable a supply authority to assess equipment regarding harmonic disturbance and to decide whether or not the equipment is acceptable for connection with regard to the harmonic distortion aspect.

The European standards, IEC 61000-3-2 & 61000-3-4, placing current harmonic limits on equipment, are designed to protect the small consumer's equipment. The former is restricted to 16 A; the latter extends the range above 16 A [6].

IV. EXISTING METHODS TO IMPROVE POWER QUALITY

With the extensive use of solid state AC–DC conversion, the power quality has become an important issue. These Improved Power Quality Converters (IPQC) are classified in four major categories, namely boost, buck, buck–boost, and multilevel converters with a high level of power quality at the input AC source and at DC output. Fig 2 shows the classification of AC-DC converters.

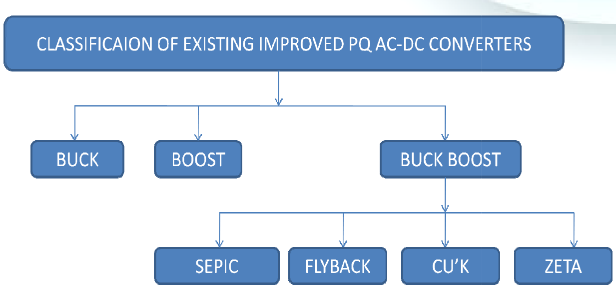

Fig 2 Classification of Improved PQ AC-DC converters.

These AC-DC converters are developed using HF transformer isolation with single or multiple outputs in buck and boost categories, namely, forward, push-pull, half bridge and full bridge and in buck-boost configurations of flyback, CUK, Single Ended Primary Inductance Converter (SEPIC), and Zeta types of converters. They are available in varying power from milliWatts (mW) to several KiloWatts (kW) for the use in small instruments to telecommunication power supplies. Furthermore, the advancement in integrated magnetics technology employing several inductors and HF transformer into one core provides a compact, small size, lowcost and reduced component count, modular and efficient AC-DC converters for use in computers and other similar sectors. One of the important reasons for such tremendous development of these isolated AC-DC converters is the availability of HF in the range of hundreds of kiloHertz (kHz) solid-state switching devices, namely, MOSFETs (Metal Oxide Semiconductor Field Effect Transistors) which have a high level of performance because of their high switching capability with almost negligible losses. However, in few applications specially designed BJT (Bipolar Junction Transistor) and IGBTs (Insulated Gate Bipolar Transistor) are used with reasonable switching frequency (in the range of tens kHz). Moreover, many manufacturers are developing dedicated power modules for the use in specific converters to reduce their losses, size, weight, and cost.Another set of important components required in these converters technology is sensing devices used in feedback current and voltage loops. Because of heavy cost constraints, a lowcost current and voltage sensors are preferred in these converters. A major reason for such development of these converters is fast growth in microelectronic devices. Due to high volume requirements, many manufacturers such as Unitrode, Analog Devices, Siemens, Fairchild, National Semiconductor, etc., have developed many dedicated integrated chips (ICs), consequently, cost effective and compact closed loop control circuitry of these

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converters with adequate speed and accuracy are obtained. There are a number of Application Specific Integrated Circuits (ASICs) available for dedicated applications.

Moreover, due to the importance of enhancing the power quality, several standards are imposed on the users and manufacturers of these converters. A variety of instruments are available to measure the performance of AC input in terms of powerfactor (pf), Crest Factor (CF), Total Harmonic Distortion (THD), Harmonic spectrum, Displacement Factor (DF), Volt Amperes (VA), Volt Ampere Reactive (VAR), Watt (W), energy consumed, at AC mains and voltage ripple, sag, surge, swell, notch, etc. These measuring instruments are known as power analyzers, power scopes, power monitors, spectrum analyzers, etc.

Various bridgeless converter configurations have been explored to mitigate power quality problems. A boost converter is a common choice as a PFC in various industrial applications. However, it cannot be used if a wide range of AC mains voltage is to be taken care of. Similarly, due to limited output voltage range buck converters are not preferred for computer power supply.

Nonisolated buck-boost Powerfactor Corrected (PFC) converter configurations are the best suited for maintaining a constant DC output voltage irrespective of wide variations in AC supply voltages.

V. LIMITATIONS OF EXISTING SYSTEM

The buck converter has the capability of naturally limiting the inrush current and protecting against overload. However, in order to operate at high power factor, the DC output voltage must be much lower than the AC input peak voltage, Consequently the power semiconductor are subjected to high Root Mean Square (RMS) current stress. It seems that this converter has no future in power factor correction applications.

The boost converter, that has been found wide utilization in the industry is not naturally isolated and operates only as a stepup voltage. Yet, it is not capable of protecting itself against a load overcurrent or short circuit.

The buck-boost converter can be easily isolated, operates as stepdown and stepup voltage, and is capable of limiting both the load and the inrush current. As a matter of fact, so far, it has been the only converter capable of satisfying all the mentioned specifications simultaneously.vA conventional buck-boost converter has a low component count. However, the output current is pulsating in nature which increases the ripple in voltage.

The CUK and SEPIC converters are naturally isolated and operate as stepdown and stepup voltage. However, they do not protect themselves against overload neither. Another practical difficulty that exists with these three converters is that an additional circuit is needed to limit the inrush current. The CUK converter is not preferred due to the polarity of the output being reversed which gives rise to various design issues. SEPIC also depicts a pulsating output current. As the output stage of the power supply is very sensitive, this pulsating current is not desirable. The flyback converter suffers from leakage inductance problem which imposes a limit on its rating.

To eliminate these issues, a Zeta converter can be employed as a PFC converter [8]. With the exception of the Zeta converter, all others have been employed to correct the power factor of power supplies, both in continuous and discontinuous current mode. A Zeta PFC converter is still unexplored for the development of computer SMPSs that are capable of drawing a purely sinusoidal current with unity PF, offering low rippled output which is the prime requirement of personal computers (PCs) [10].

VI. ZETA CONVERTER

This converter is the latest addition to this family of singlestage input current shapers. It also uses single switching device and inherently provides an inrush current, overload, and short circuit protections. It can operate in continuous conduction mode (CCM) as well

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as discontinuous conduction mode (DCM) with improved power quality at input AC mains. These converters are also called resistance emulators as they behave as a resistive load to input AC mains. Fig 3 shows the circuit diagram of Zeta converter.

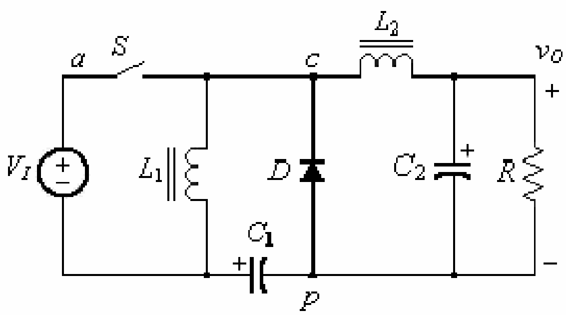

Fig 3 Circuit diagram of a Zeta converter

Zeta converter has the following advantages;

- Provides a noninverted output.
- Low ripple content in the output voltage.
- Circuit losses is less compared to SEPIC converter.
- It can stepup or stepdown output voltage as it is a type of buck-boost converter.
- It has an inherent property of limiting inrush current.

VII. APPLICATIONS OF ZETA CONVERTER

Zeta converter finds application in automotive battery chargers, telecom industries, and photovoltaic systems. These converters are widely used to maximize the energy harvest for photovoltaic systems and for wind turbines to regulate the output voltage. Zeta converters are also used in powerfactor correction in power grids and various motor drives especially Brushless DC (BLDC) motors. Zeta converters can be efficiently used in SMPS to improve power quality of personal computers.

VIII. SIMULATION

To verify and investigate the performance of the preliminary stage, a simulation study of Zeta converter in closed loop is performed for input AC voltage of 220V at 50Hz and output DC voltage of 220V and 350 W output power rating with a switching frequency of 20 kHz, with RL load. Table 1 shows the specifications of the simulation. The simulation was done using MATLAB/Simulink-2014 software.

TABLE 1
SPECIFICATIONS FOR SIMULATION.

Specifications	Values
Input Voltage	220 V , 50 Hz AC
Switching Frequency of switch	20 kHz
Power Rating	350 W

Simulation setup of Zeta converter with closed loop control is shown in fig 4. AC input voltage and input current is shown in fig 5. The THD for input current waveform is shown in fig 6.

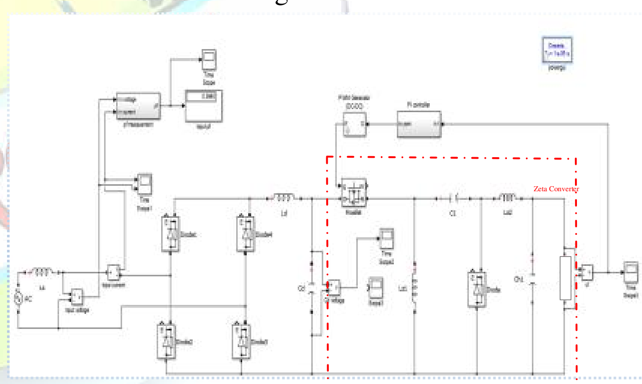

Fig. 4 Simulation setup of Zeta converter with closed loop control

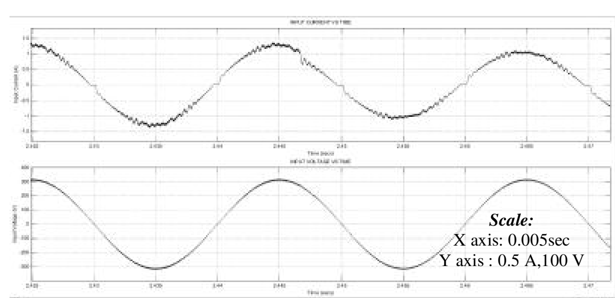

Fig 5 Input voltage and input current

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It can be seen from fig 5 that the input current is sinusoidal and has lesser distortion when Zeta converter is employed in the SMPS.

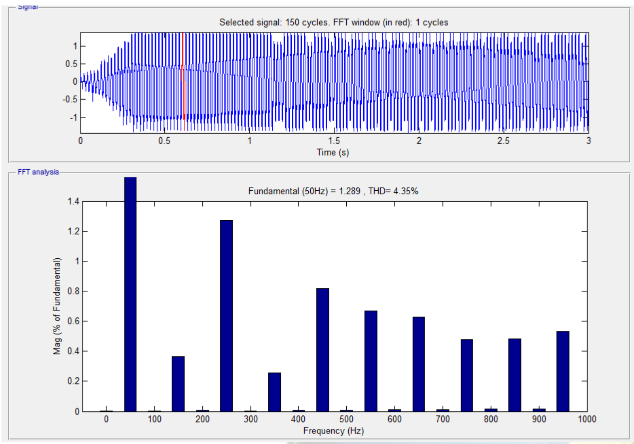

Fig 6 Total Harmonic Distortion for input current waveform

The THD of the input current is found to be 4.35 % which is within the limits specified by International standards. The THD has improved by 105% with the use of Zeta converter.

IX. CONCLUSION

The conventional SMPS for computers does not meet the international power quality standards. Various topologies of IPQC are being used today to improve the power quality in SMPS. Buck-boost configuration is most suited for SMPS application as they can stepup and stepdown of voltages. Zeta converters which are of a buck-boost configuration can improve power quality to meet the power quality standards. It can be recommended as a tangible solution for computers and other similar appliances.

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