A Review and Comparative Study on Single-Phase Ac-Dc Converters for Their High Frequency Applications

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***Abstract*— Due to large application of converters in the system the power quality at input mains affect system drastically so to improve system quality various techniques to be use, this paper contain various AC to DC converter techniques that not only provide better DC output but also improve power quality at input mains. This paper contains introduction, converter classifications, comparative converter performance, application, future trend.**

***Index Terms*— AC-DC Converters, Harmonics reduction, Isolation transformer, power quality enhancement, Power-Factor improvement**

I. Introduction

Because of the presence of MOSFET (a high frequency switching device) the wide development of AC-DC converters are going to perform in the hundreds of KHz ranges [3]. MOSFET's High performance switching capabilities and avoidable losses are a big factor for the research and commercial uses.

AC-DC converters with high-frequency switching operations are developed in large rating from the few watt (W) applications to several KW like computer power supplies, UPS, battery charge, Electric heating, welding operations, electronic heat ballast, medical instruments, compressors, telecom application and fan ADS operations. BJT and IGBTs are also used for some special applications. Although besides MOSFET, BJT and IGBTs, many researchers and manufactures are continuously working to develop dedicated power models to reduce the losses of converters and the improved device performance.

As the microelectronics is continuously spreading their area and because of the high volume requirement in a small area many developer has developed a lot of dedicated ICs [4], [5] and new converters having a voltage and current's feedback loops.

Based on the voltage level AC to DC converters also feeds various loads and based on the input – output voltage levels converter classified as Buck, Boost, Buck-Boost converter.

Various converters have been presented in the last few decades for their application perspective views such as digital signal processing [6], optimized no of elements in a circuit[7], regulator application (dc)[8], various current conduction modes[9], various control methods[3][4], magnetization applications[10][11] , circuit integration[4][5].

The immoderate presences of AC-DC converter in a large number of fields severely affect the power quality, in that condition power factor correction and harmonic content reduction become the considerable issue. Because of the need of the power quality improvement, several standards [1][2], are imposed on the users and manufacture of these converters. So to maintain efficient and optimized power quality in the system various power correction (PFC) techniques are uses. These PFC techniques are either Active or Passive, A Passive method uses tuned LC filters, that gives a robust operation but besides this also have large size, weight, volume, and may not respond adequately if power factor varies, whereas active filter(methods) are more efficient solution and vary as per the power factor varies by solid state switch.

II. Introduction Various AC-DC Converter for Power-Quality Improvement

All these below converters along with the basic diode bridge circuits at input side used for AC to DC conversion to feed various kind of loads and they configure in total 12 basic circuit topologies. Although, several researchers are continuously working to further improve the performance characteristics of the converter and a lot of modified circuits have already being listed and the further researched Boost converter will also explain in this paper.

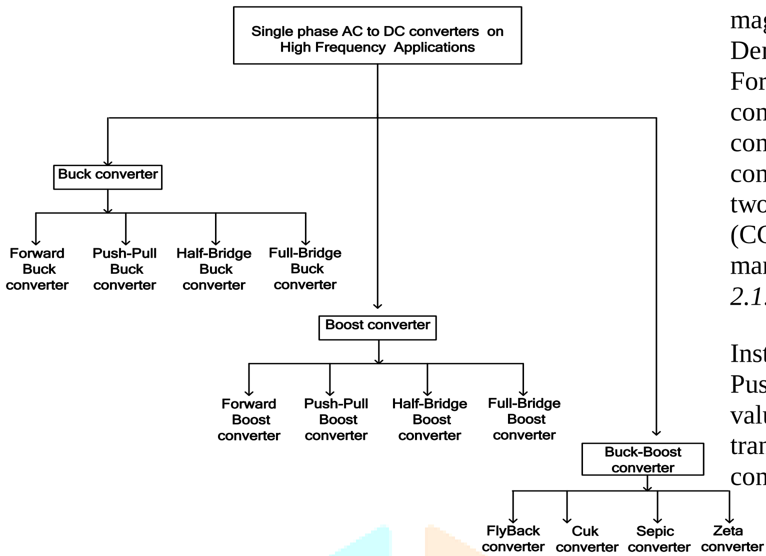

Fig.2.Single Phase AC to DC converter classification based on High Frequency Application.

Several points like cost, size, density, robustness, efficiency, complexity, performance etc must be consider during the converter selection for a given application And the boost PFC circuit working in continuous conduction mode (CCM) is popular choice for medium and high power application because of low EMI in input current compared to other active converters topologies such as buck-boost and buck converter

2.1. *Buck-Converter:*

2.1.1Buck-Forward AC-DC converter:

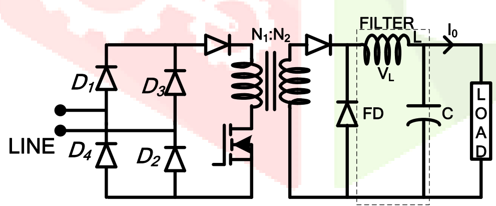

Fig.2.1.1 (a) Ideal Forward type Buck AC-DC converter

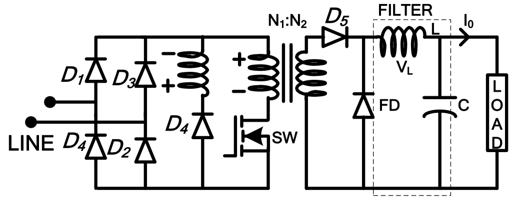

Fig.2.1.1 (b) Practical Forward type Buck AC-DC converter

In case of practical configuration in forward Buck type AC-DC converter the tertiary winding provides the path for the flow of magnetic current during MOSFET off state i.e. Transformer is magnetize through primary winding when MOSFET is on and Demagnetize through Tertiary winding when MOSFET is off. Forward converter uses Unidirectional Core Excitation. Forward converter is uses for below 400W power rating and output DC is controlled by feedback in the controller [12]. Although Forward converter working on a lot of different configurations like using two devices [13], multi output and continuous current mode (CCM) [14], Discontinuous Current Mode (DCM) [15] and many more having a few Watt to KW range operations [12][15].

2.1.2Buck Push-Pull AC-DC converter:

Instead of Unidirectional Core Excitation in forward converter Push-Pull converter uses Bidirectional Core Excitation. A small value capacitance used after the diode bridge rectifier and before transformer to work as a voltage source type for the Push-Pull converter [11][3].

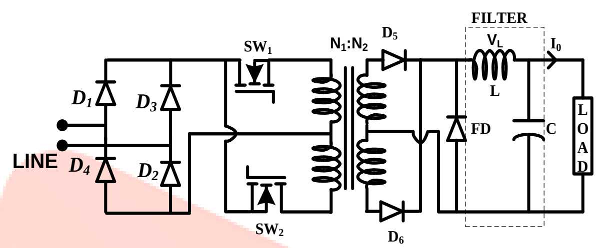

Fig.2.1.4 Push-Pull type AC-DC Buck converter

Filter at the input side can be used to remove EMI, RFI noise and switching frequency interference. A lot of circuits [4],[5] have been introduced for the Push-Pull design to further enhance the power quality and circuit performances.[16]

2.1.3Half-Bridge Buck AC-DC Converter

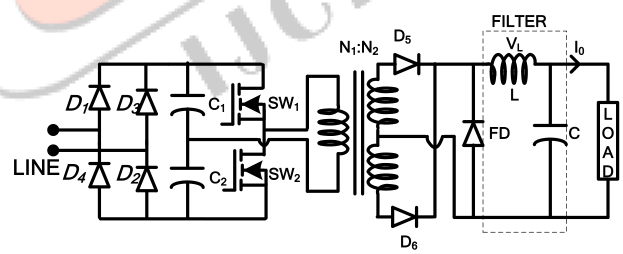

Fig.2.1.3 Half-bridge ac-dc buck converter

Capacitors (C_1 and C_2) used at the input side to provide two AC terminals for the converter which constraints its operation within low power applications. For Half-Bridge converter also a lot of configurations and techniques like Zero Voltage Switching (ZVS) and resonant soft switching have been introduced that further enhance the converter performances.[4][5]

2.1.4Full-bridge ac-dc buck converter

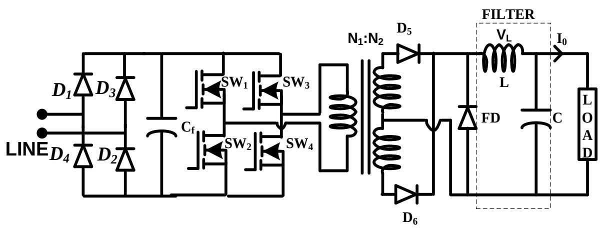

Fig.2.1.4 Full-bridge ac-dc buck converter

The bridge converter configuration can provide both unipolar and/or bipolar switching capabilities, although the size of filter and the transformer size are higher in the Bipolar switching bridge Converter configuration. Bridge configuration can have high power working capability but Push-Pull configuration have reduced losses and high efficiency. This configuration can be use for the Uninterruptable Power Supply (UPS) operations. Soft switching operation has been discussed in [17] and Zero Voltage Switching (ZVS) in [18].

2.2 *Boost-Converter:*

An inductor is present in line after the Bridge configuration to get the current source configuration and the DC current source used for the feeding to the converter and the control technique is also feedback current controlled.

2.2.1Forward boost ac-dc converter:

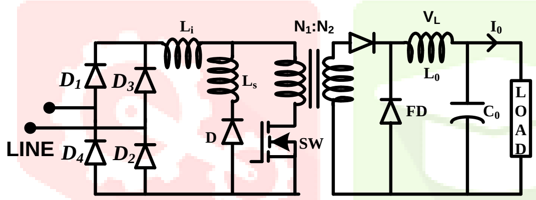

Fig.2.1.4 forward type AC-DC Boost Converter

It needs small value of inductor L_i that provide high value of power quality performance. Boost cell need only one inductor and that reduces the cost, size and losses of the boost converter. Many converter configurations such as CCM/DCM [14][15][19], ZVS[20] and zero current transaction[21] are used to improve performances.

2.2.2Push-Pull Boost AC-DC Converter:

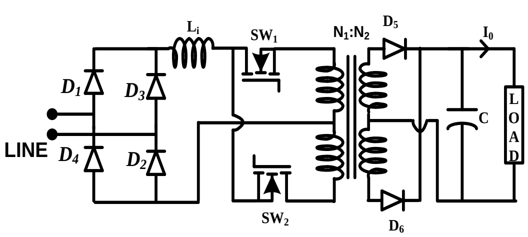

Fig.2.1.4 Push-Pull type AC-DC Boost Converter

A small value of inductor L_i provide high value of power quality performance [22]. This configuration uses for high power rating applications because of transformer's complete utilization. Some modified configurations such as flyback current fed [23], with ZVS/ZVC [24], active clamp and voltage doublers [25] etc.

2.2.3Half-bridge boost ac-dc converter:

For very low output DC voltage a self-driven synchronous rectifier is preferred to further enhance the converter efficiency [26].

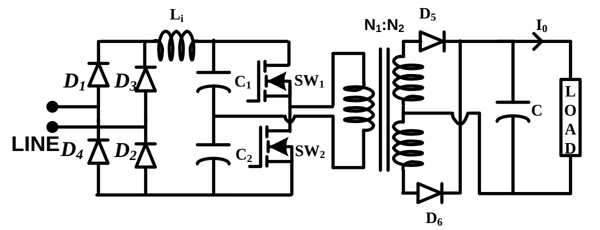

Fig.2.1.4 Half-Bridge type AC-DC Boost Converter

Converter operates in the DCM modes and achieve high power factor and reduced harmonics in AC mains. Several modifications such as symmetrical [27], symmetric transformer [28], diagonal switches [29], voltage doublers [30][31]. Their applications in Emergency lights [32], battery charging [33], UPS [34], telecom sector [27] and PMBLDCM drives [35][36].

2.2.4Full-bridge boost ac-dc converter:

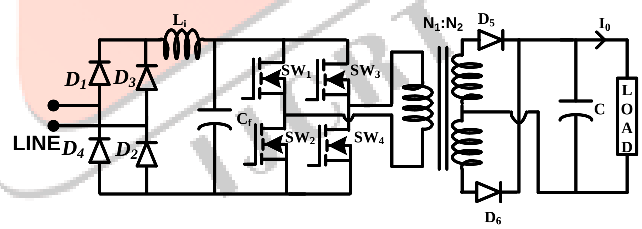

Fig.2.1.4 Full-Bridge type AC-DC Boost Converter

Diode bridge configuration is preferred over all other rectifier configuration for the high frequency applications. An inductor in series with MOSFET H-Bridge switch circuit is used to provide the Boost Converter operation. Modified circuit configurations such as Boost converter fed full-bridge [37], ZVC/ZVS with resonant circuit [38] and with two series connected transformers [39]. Their applications in UPS [17], telecom power supply [40], PMBLDCM drive [41].

2.3 *Buck-Boost AC-DC Converters:*

It all converter types operate with single switching device (MOSFET) and offer Buck-Boost qualities between input and output. Because of fewer components less size, cost, weight and high performance characteristics can be achieved with lesser loss. Can be operates either in continuous or discontinuous mode of operations.

2.3.1Flyback AC-DC Buck-Boost Converter:

This converter also uses Unidirectional Core Excitation like forward converters.

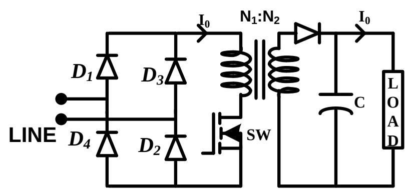

Fig.2.3.1 flyback AC-DC Buck-Boost Converter

It is very famous for the low power applications, not only the converter but also its variations like active clamp [42], quasi-resonant ZCS, resonant charge pump circuits [43], CCM/DCM operations [44], etc. This is mainly uses for the Voltage matching, Electrical safety, Cost reduction, simple control with less sensors etc.

2.3.2Cuk ac-dc buck-boost converter

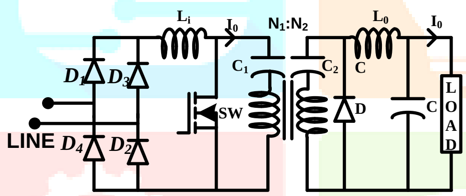

Fig.2.3.2 Cuk AC-DC Buck-Boost Converter

It is also known as the Ideal Current Shaper because of the converter's inbuilt current shaping quality at the DCM for constant frequency [45]. It also provides an operation with low-noise level, integrated magnetic property in which transformer and input-output inductors are on the same core. This integrated magnetic provide less switching current ripples, wide voltage range at input and output side, reduced size, inbuilt inrush protection, high performance and high efficiency.

2.3.3Sepic ac-dc buck-boost converter

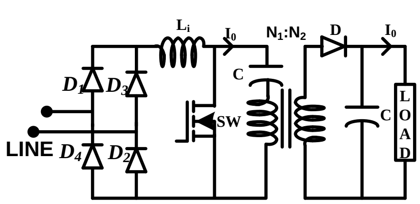

Fig.2.1.4 Sepic ac-dc buck-boost converter

Single-phase Single Ended Primary Inductance Converter (SEPIC) is having inbuilt Power Factor Correction pattern with less component and converter size that gives high Reliability, Efficiency and Power-Factor. It also gives low THD, CF and high PF at input mains [46],[47].

2.3.4Zeta ac-dc buck-boost converter

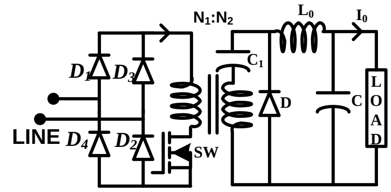

Fig.2.1.4 Zeta ac-dc buck-boost converter

This is the recent addition to this converter family and also known as the Resistance Emulators because of resistive load behavior at the supply mains. This is the single stage input current shaper uses only single MOSFET switching element. It provides inbuilt inrush, overload and short circuit current protections.

III. Introduction Comparison of Converter Performance

In the continuous conduction mode (CCM) of operation for Total Harmonic Distortion (THD) in the input side current waveform by the converters can be arranged in the following manner: Full bridge buck < Forward Boost < Forward Buck < Zeta < Flyback < Half-Bridge Buck < Push-Pull Boost < Push-Pull Buck < Cuk < SEPIC < Full-Bridge Boost

Whereas in case of Discontinuous Mode of operation given as: Cuk < Zeta < SEPIC < Flyback < Full-Bridge Boost < Half-Bridge Buck < Forward Boost < Full-Bridge Buck < Half-Bridge Boost < Push-Pull Boost< Push-Pull Buck < Forward Buck

The single-switch topologies can be preferred in sequence of Flyback, Zeta, Cuk and SPIC converter because Zeta and Flyback having inbuilt Inrush and Over current protection compare to SEPIC and Cuk and the Cuk converter having smaller core that gives lesser losses. Control and protection scheme have a vital role in the noise and EMI reduction instead of this the Processor speed and sampling frequency of the sensor decide rise and response time of the converter. The Push-Pull and the Half-Bridge converters have the same switching losses instead of single switching converters.

For the particular converter selection these are some selection criteria which have been decided:

1. Ratings
2. Input power quality (PF, THD, CF, DF etc.)
3. Output power quality (VRF, RF, Regulation, Sag, Swell etc.)
4. Type of Load (Linear, nonlinear, variable, constant, time dependent, time independent etc.)
5. Number of outputs
6. Cost
7. Size

8. Weight
9. Efficiency
10. Noise level (EMI, RFI, etc)
11. Reliability
12. Type of output (Buck, Boost, Buck-Boost)
13. Environmental Factors and Effects (temperature, humidity, cooling, pollution level etc.)
14. Miscellaneous Factors (Magnetic materials, Switching Frequency, Solid state device type, etc.)

In CCM mode operation the convertor preference based on Cost factor is as follow: Low Cost: - Forward Buck, FlyBack, and Forward Boost. Medium Cost: - Push-Pull Buck, Half-Bridge Buck, Push-Pull Boost, Half-Bridge Boost, Cuk, SEPIC, Zeta. High: - Full-Bridge buck Highest: - Push-Pull Boost, Half-Bridge Boost [48]

In CCM mode operation the convertor preference based on Cost factor is as follow: Lowest cost: - Forward Buck Low Cost: -, FlyBack, Cuk, SEPIC, Zeta. Medium Cost: - Push-Pull Buck, Half-Bridge Buck, Push-Pull Boost, Half-Bridge Boost, And Forward Boost. High: - Full-Bridge buck, Full-Bridge Boost.[48]

For converter's Efficiency point of view: Buck Forward converter having 75-80% [49], Forward Boost 75-90% [19] Push-Pull Buck 85-90% and Push-Pull Boost 95% [25], Half-Bridge Buck and Half-Bridge Boost 80-90% [34], Full Bridge Buck 85-95% [50]and Full-Bridge Boost 75-95% [51][52], Buck-Boost 90-95% in which Flyback 91.3% [53], Cuk Converter 95.2% [54], SEPIC 91.5% [55] and Zeta [56]. More Comparative studies have been given in [48].

Major Applications of the AC-DC converters:
1. Personal Computers (PC)
2. Laptop Computers
3. Work Stations
4. Printers
5. Scanners
6. Fax machines
7. Cordless Phones
8. Mobile Phones
9. Copiers (Xerox machines)
10. Telecom power supplies
11. Battery Chargers
12. UPS
13. Electrical Vehicles
14. Measuring instruments & Testing instruments
15. Medical Equipments
16. Induction Heaters
17. Lighting Industries with Electronic ballasts for various type Bulbs
18. Welding units
19. Microwave heating
20. Dielectric heating
21. Small ovens
22. ASDs in Refrigerators
23. Heating
24. Ventilation
25. Air-conditioning
26. Boiler feed pumps
27. Fans
28. Domestic applications (Washing Machine) etc. [ ]

IV. FUTURE TRENDS

Sensor reduction reduces the losses in the system and the Development of Dedicated Specific Application Integrated Circuits (ASCIs) further reduces the size and cost of the system. Magnetic material improvement is also the focused research point that again reduces size of transformer required for isolation. Development of Integrated Power Module (IPM) also improves system performances. Digital Signal processor (DSPs) and Digital Signal Controller (DSC) improve the control strategies for the converters. Mosfet is the switch selection for the HF operations however this is the potential research area to guide the new technology.

V. CONCLUSION

A Review study on the AC-DC converter with some comparative study has been discussed in this paper and that contain sufficient information for the researchers, manufacturers and engineers for the base study. All 12 AC to DC Converter circuits defined that contain neat Circuit Diagrams for easy understandings.

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