Single Switch AC-DC Cuk Converter for Power Factor and Efficiency Enhancement

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Abstract:- In this paper, Performance of Cuk ac–dc converter is presented with hysteresis current and voltage loop. DC- DC converter is used to calculate the power . To reduce the harmonics filters are designed. In this paper shunt active filter is used to reduce the harmonics. Switching sequences is controlled by using Hysteresis Current controller. It improves the output of the converter. Converter is operates in two modes one is voltage controller mode and another is current controller mode. Power factor correction is used in input side to regulates input dc bus, controller is used in output side to regulate the output bus voltage. In this paper, converter operation is discussed to explained and described the controlling strategy and total harmonic distortion of input current. Finally all operation is compared with steady-state behavior, THD, and efficiency.

Keywords:- *Alternative current (AC), Direct Current (DC), Hysteresis Current Control (HCC) Technique**,** Power factor, Pulse width Modulation (PWM), Single Stage Converters.*

I. INTRODUCTION

Higher power ac–dc converters are required to have some sort of power factor correction (PFC) capability to comply with harmonic. PFC methods can generally be divided into the following three categories:

- Passive PFC converters: Passive PFC is used to reduced the current harmonics by using passive elements like capacitor and inductor. They are helpful to meet more sinusoidal waveform. These converters are heavy in weight and more expensive compared to other converters. They are used in some places like heavy industries for heavy motor load.

- Two-stage converters: Two stage converter perform function in two steps. In the first step, it consist ac-dc boost pre-regulator converter to give shape in input converter and in second stage isolated dc-dc converter is performed function for required output voltage. In a Two-stage converters, two separate switch-mode converters are used with its own controller. Using two converters, it increase the cost of overall system. Under the light load condition, it has poor efficiency. There are two converter stages that are operating each with its own set of fixed losses while a small amount of power is actually transferred to the load. These fixed losses are dominant under light-load operating conditions.

- Single-stage converters: In this single phase full bridge converter is used by performing ac-dc conversion and then dc-dc conversion. There are numerous publications about single-stage PFC (SSPFC) converters particularly for low-power ac–dc fly back and forward converters [1]–[4]. Research on the topic of higher power ac–dc single-stage full-bridge converters, however, has proved to be more demanding, and thus, there have been much fewer publications [5]–[14]. Previously proposed single-stage ac–dc full-bridge converters have the following drawbacks:

➢ In a some full bridge ac circuit boost inductor converters are connected in input side. Although they can achieve a near-unity input power factor, they lack an energy-storage capacitor across the primary-side dc bus, which can result in the appearance of high voltage overshoots and ringing across the dc bus. It also causes the output voltage to have a large low-frequency 120-Hz ripple that limits their applications [7].

➢ Some are resonant converters [11], [12] that must be controlled using varying switching-frequency control, which makes it difficult to optimize their design (especially their magnetic components) as they must be able to operate over a wide range of switching frequency.

➢ Most are voltage-fed, single single-stage, pulse width modulation (PWM) converters with a large energy storage capacitor connected across their primary-side dc bus. These converters do not have the draw-backs of resonant and current-fed SSPFC converters. They operate with fixed switching frequency, and the bus capacitor prevents voltage overshoots and ringing from appearing across the dc bus and the 120-Hz ac component from appearing at the output. Voltage-fed converters, however, have the following drawbacks:

➢ The primary-side dc-bus voltage of the converter may turn out to be extreme under high input-line and low-output-load conditions. This is because SSPFC converters are implemented with just a single controller to control the output voltage, and the dc-bus voltage left unregulated. [7].

- The high dc-bus voltage results require for higher voltage rated devices and very huge bulk capacitors for the dc bus. For example, the converter has a dc-bus voltage of 600 V in A single-stage zero-voltage zero-current-switched full-bridge DC power supply with extended load power range,‖ proposed by P. K. Jain, J. R. Espinoza, and N. Ismail, [6].
- The current fed converter has a high power factor but in case of voltage fed converter the power factor is low at the input side. For an instance, the converter has an input current that is neither uninterrupted nor irregular, but is semi continuous with a considerable amount of deformation which was proposed in ―An improved AC–DC single-stage full-bridge converter with concentrated DC bus voltage, by P. Das, S. Li, and G. Moschopoulos, [8].
- The converter is prepared to operate with an output inductor current that is alternating for all operation conditions or some parts of operation conditions to try to avoid the dc-bus voltage from becoming excessive [6], [8], [14].
- Output inductor current and dc-bus voltage are related, as shown in ―PWM full-bridge converter with natural input power factor correction,‖ proposed by G. Moschopoulos, Q. Mei, H. Pinheiro, and P. Jain. Doing so results in the need for components that can handle high peak currents and additional output filtering to remove ripple. [6].

Problems associated with single-stage converters; excessive dc-bus voltages due to the lack of a dedicated controller to regulate these voltages, large output ripple, distorted input currents, reduced efficiency (particularly for low input line voltages due to a low dc-bus voltage generally exist for two-level single-stage converters, such as the ones shown in Fig. 1 and three-level converters [11], [12]. In the paper, a new single-stage ac–dc converter that does not have the drawbacks of previously reposed single-stage and two-stage converters is proposed. The paper introduces the new converter, explains its basic operating principles and its modes of operation, and discusses its features and its design The open loop control of a three level integrated ac-dc converter proposed by Mehdi Narimani, Student Member, IEEE, and Gerry Moschopoulos, Senior Member, IEEE has very less output voltage To regulate the excessive dc bus voltages, minimize the large output ripples, distorted input currents and for better output voltage there is a need for a converter, which overcomes all these drawbacks. In this paper, a hysteresis control of a single stage three level integrated ac–dc converter that does not have the drawbacks of previously proposed single-stage and two-stage converters is proposed.

II. CONVERTER DESIGN

Design of different integrated ac-dc converter are given below. A procedure for the design of the converter is presented in this section and is demonstrated with an example. The converter is to be designed with the following parameters for the example,

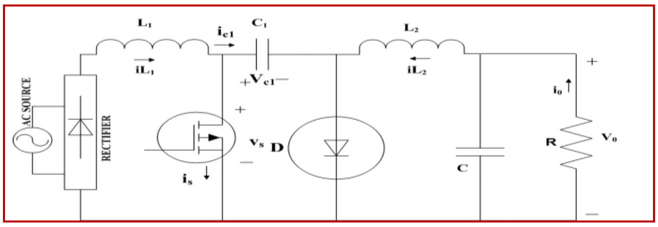


Fig 1:- Cuk AC-DC Converter

The Cuk Converter is basically used for the current balance of capacitor and transfers the capacitive energy to balance the current. The Cuk Converter is derived from duality principle on the Buck-boost Converter. The main feature of the Cuk Converter is that both the input and the output current are non- pulsating. The disadvantage is the use of capacitor C1 requires a large ripple current carrying capability.

III. CONTROL STRATEGY

This converter provides a regulated dc output voltage under varying load and input voltage conditions. The converter component values are also changing with time, temperature and pressure. Hence, the control of the output voltage should be performed in a closed-loop manner using principles of negative feedback. The two most common closed- loop control methods for PWM dc-dc converters, namely the voltage-mode control and the current mode control [16].

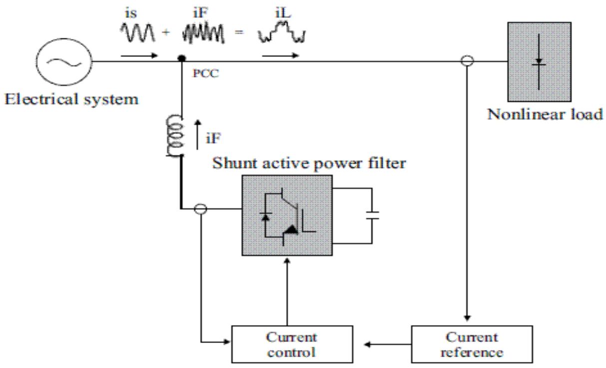


Fig 2:- PFC Techniques

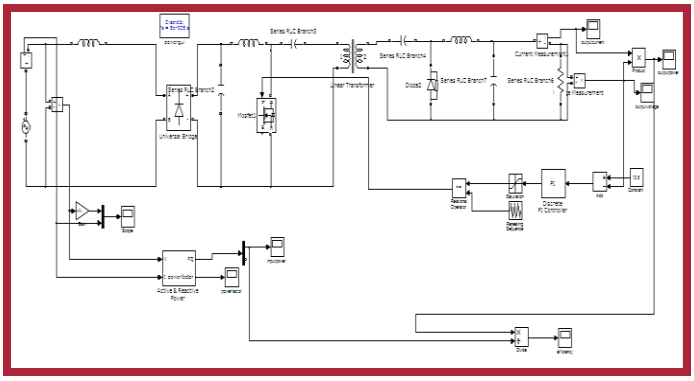
A. Voltage Mode Control:- In voltage control mode, converter fee back voltage is achieved from the resistive voltage divider and regulates the output voltage. It is compared with an accuracy external reference voltage, Vref in a voltage error amplifier. A saw tooth constant amplitude amplifier is used to compare with the control voltage by using the error amplifier. The PWM Modulator or the comparator produces a PWM signal that is fed to drivers of controllable switches in the dc-dc converter. The duty ratio of the PWM signal depends on the value of the control voltage.

B. Current Mode Control:- In current mode control, there are many advantages of current mode control over voltage mode control. Voltage being an accumulation of flux, which is slow in time as far as control mechanism, is worried. By using Hysteresis Current Control, switch mode power supply is used to develop a new area in power supply. Here, the average or peak current is employed in the feedback loop of the switch mode power converters. It has given new avenues of analysis and at same time introduced complexities in terms of numerous loops.

C. Hysteresis Current Control:- The PFC of boost converter with CCM condition is possible with certain control strategy (Moon etal.,2011; Roggiaetal.,2012). Among all the various control techniques, Hysteresis Current Control (HCC) is broadly used technique owing to its non-complex execution, fast response, enhanced system stability and less distortion in input current waveform (Zhouetal.1990).In this study, for regulating the output voltage and wave shaping, HCC technique is used. Different current control techniques are usually used for controlling the PFC converters. For implementing the closed loop control, the supply voltage and the output voltage, input current of the boost converter are sensed. In outer voltage control loop, the boost converter output voltage is scaled down and compared with the reference value. The difference is given to the PI controller. The sine shape obtained from the supply voltage is multiplied with the output of PI controller and the resulting signal sets the reference current. In Hysteresis current control, depending upon the inductor current becomes less than the lower reference (IL, ref) the switch is turned ON and if it exceeds the upper reference (IU, ref) the switch is turned OFF. This results in variable frequency operation. A small Hysteresis prohibit deselected in order to decrease the ripple in the boost inductor current.

IV. SIMULATION RESULTS AND DISCUSSION

Simulation Model of Cuk Converter:



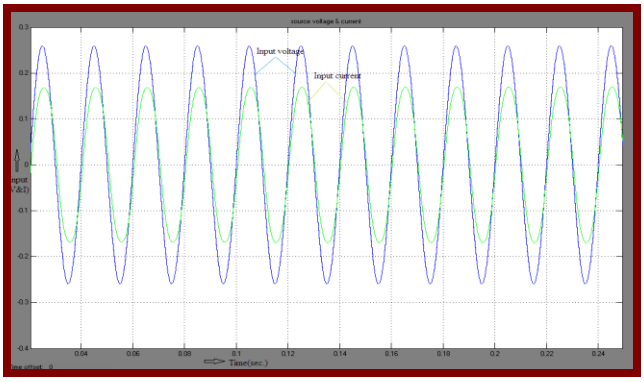


Fig 3:- Source voltage and current of Cuk converter in DCM at100% load

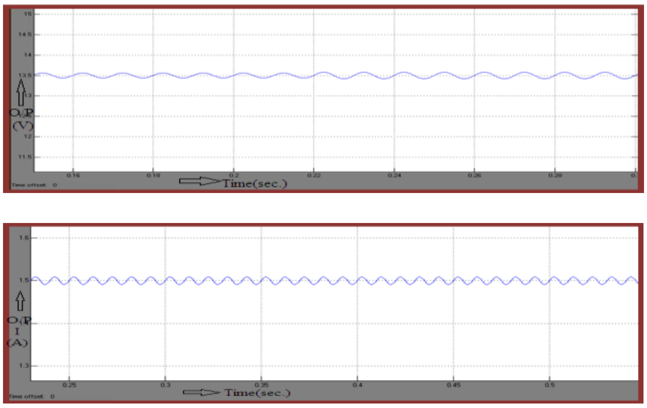


Fig 4:- Steady state output voltage & current of Cuk converter in DCM at 100% load

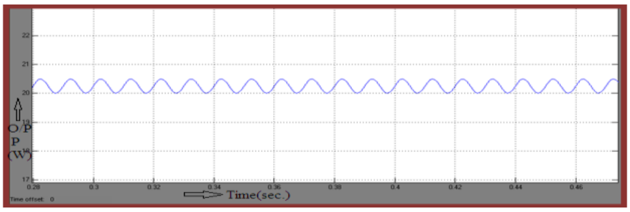


Fig 5:- Steady state output power of Cuk converter in DCM at100% load

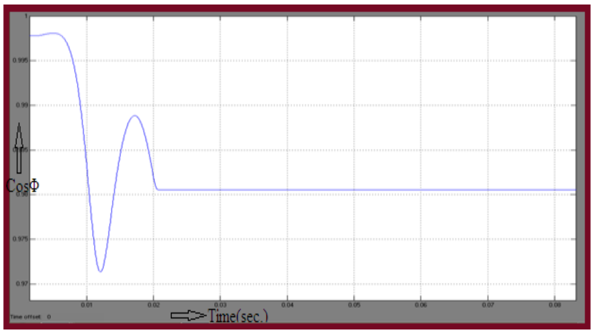


Fig 6:- Steady state input power factor of Cuk converter in DCM at 100% load

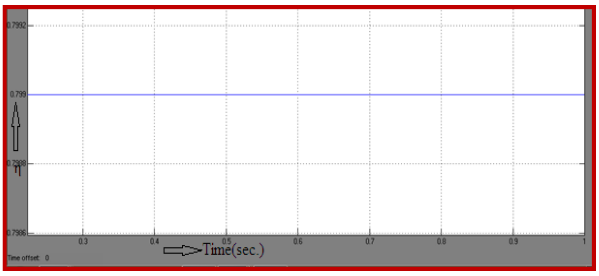


Fig 7:- Steady state efficiency of Cuk converter in DCM at100% load

The efficiency of Cuk converter more than 79.8%, less than 1%.

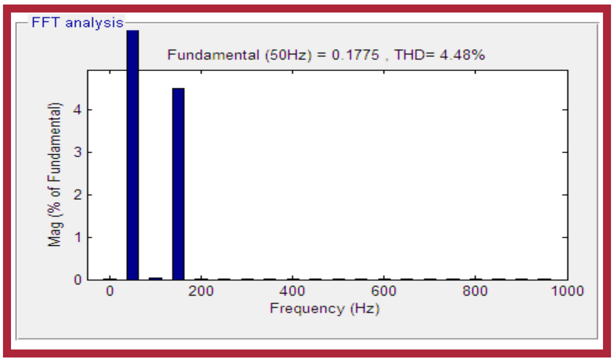


Fig 8:- The input current THD of Cuk converter at 100 %load

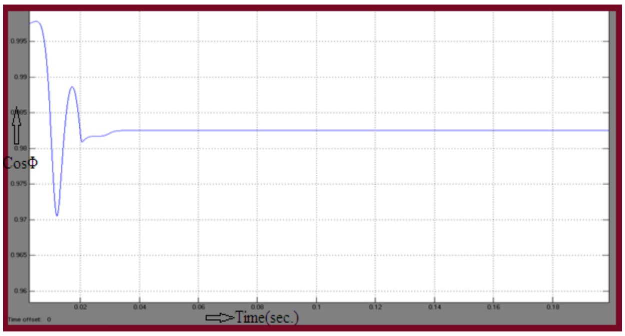


Fig 9:- Steady state input power factor of cuk converter in DCM at 50% load

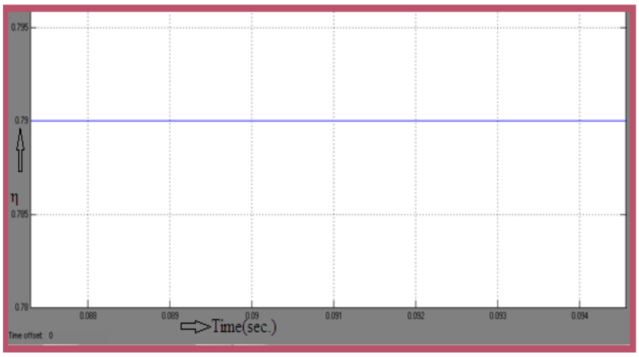


Fig 10:- Steady state efficiency of Cuk converter in DCM at 50% load

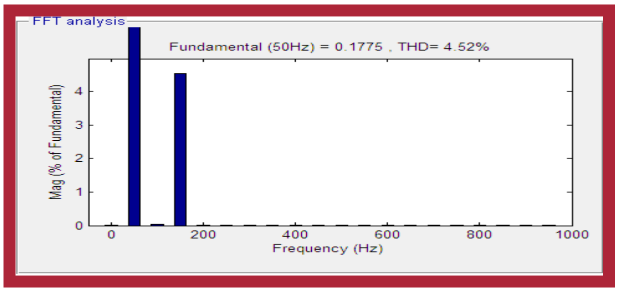


Fig 11:- The input current THD of Cuk converter at 50 % load

The fig shows waveforms for the input voltage and current in rectification mode. The voltage wave form and current waveform are in phase each other. It seen that the source current has negligibly small harmonic pollution and gives a unity power factor which makes the converter a nearly linear load. The converter maintain unity power factor. The line current total harmonics distortion (THD) is more than 5%. The proposed converter has the following features:

- Reduced cost compared to two-stage converters: Even though the proposed converter may seem costly, the reality is that it can be cheaper than a conventional two-stage converter. This is because replacing a switch and it is related to gate drive circuitry with four diodes reduces cost significantly even though the component count seems to be increased—this is especially true if the diodes are ordered in bulk numbers.
- Better performance than a single-stage converter: The proposed single -stage converter can operate with an better input power factor for universal input line applications than a single-controller, single-stage because it does have a devoted controller for its input section that can perform PFC and regulate the dc-bus voltage. The existence of a second controller also allows the converter to operate with better efficiency and with less output ripple as each section of the converter can be made to operate in a most advantageous manner.
- Improved light-load efficiency: The projected converter can be designed so that it has a conventional dc-bus volt-age of 400 V. Since the converter is a multilevel converter, a 400 V dc bus means that each switch will be exposed to a maximum voltage of 200 V. Having 200 V across a MOSFET device instead of 400 V (as is the case with two-level converters) results in a 75% reduction in turn-on losses when the converter is operating under light-load conditions and there is an inadequate amount to current available to discharge the switch output capacitances before the switches are turned on.
- Increased design flexibility: Since the converter is a multi-level converter, it can be operated with high dc-bus voltage (800 V), standard dc-bus voltage (400 V). There are advantages to operating with high dc-bus

voltage or with regular dc-bus voltage. The fact there is flexibility in the level that the dc-bus voltage is set means that there is widespread flexibility in the design of the converter. This gives the designer options as to how to optimize the design of the converter for other factors such as efficiency profile and cost (i.e. cost of switches based on voltage rating considerations and availability). It should be noted that this design flexibility makes the design of the three-level converter to be much simpler than that of a single-stage two-level converter or that of a single-controller three-level single-stage converter as the dc-bus voltage can be fixed to a preferred level that is considered appropriate

V. CONCLUSIONS

The analysis of single switch AC to DC converter for power factor and efficiency enhancement is carried out in DCM operation for 13.5V, 20.25W output. High power quality is obtained with design parameters with Power factor on the order of 0.99 and efficiency more than 80%. On the other hand, the forward converter shows very good efficiency, which comes out to 82.4%.

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