# Implementation of Single Stage Three Level Power Factor Correction AC-DC Converter with Phase Shift Modulation

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## Abstract

A new three-level ac–dc single-stage converter that can operate with standard phase-shift pulse width modulation is proposed in this letter. In this letter, the operation of the converter is explained, and its feasibility is confirmed with experimental results obtained from a prototype converter. Finally, the efficiency of the new converter is compared with that of a previously proposed converter of the same type, and it is shown that the new converter has better efficiency, particularly for light-load operation.

**Keywords:** AC–DC power factor correction, phase-shift modulation (PSM), single-stage converters, three-level (TL) converters.

## 1. Introduction

The ac–dc power supplies with transformer isolation are typically implemented with some sort of input power factor correction (PFC) to comply with harmonic standards .There are three techniques to satisfy these standards. One of them is adding passive filter elements to the traditional passive diode rectifier/LC filter input combination; the resulting converter is very bulky and heavy due to the size of the low-frequency inductors and capacitors. Another method is using an ac–dc boost converter in the front-end rectifying stage to perform active PFC for most applications. The ac–dc boost converter shapes the input line current as an almost sinusoidal shape with a harmonic content compliant with agency standards. Using active PFC, however, increases the cost and complexity of the overall two-stage converter because an additional switching converter must be implemented . This has led to the emergence of single-stage power-factor-corrected (SSPFC) converters. There have been numerous publications about SSPFC converters, particularly for low-power ac–dc flyback and forward converters. Research on the topic of higher power ac–dc single-stage full-bridge converters, however, has proved to be more challenging, and thus, there have been much fewer publications several single-stage ac–dc full-bridge current-fed converters have been proposed. These converters have a boost inductor connected to the input of the full-bridge circuit. 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.

The most common type of single-stage ac–dc full-bridge converter is based on some sort of voltage-fed single-stage pulse width modulation (PWM) converter; Converters of this type have a large energy-storage capacitor connected across their primary-side dc bus. They 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 single-stage PWM full-bridge converters, however, have disadvantages that have limited their use. Most of these drawbacks are because 1) they are controlled by a single controller and the dc bus voltage is left unregulated and 2) they are implemented with two-level topologies that subject the converter components to high-voltage stresses.

With multilevel topologies, the dc bus voltage can be allowed to reach higher levels that are possible with a two-level topology as the converter components are exposed to half the dc bus voltage and, thus, have half the voltage stress. Freeing up the allowable limit of dc bus voltage allows the aforementioned limitations on output and input currents to be eased so that the converter can be made to operate with an output current that has less ripple and an input current that is less distorted than that of a two-level converter.

A three-level (TL) voltage-fed ac–dc single-stage PWM converter was proposed. This topology does not have the drawbacks of previously proposed single-stage converters because of its TL structure. The PWM method that was used to operate the converter. As can be seen, this PWM method is not standard phase- shift PWM (PWM) and is therefore not found in commercially available integrated circuits.

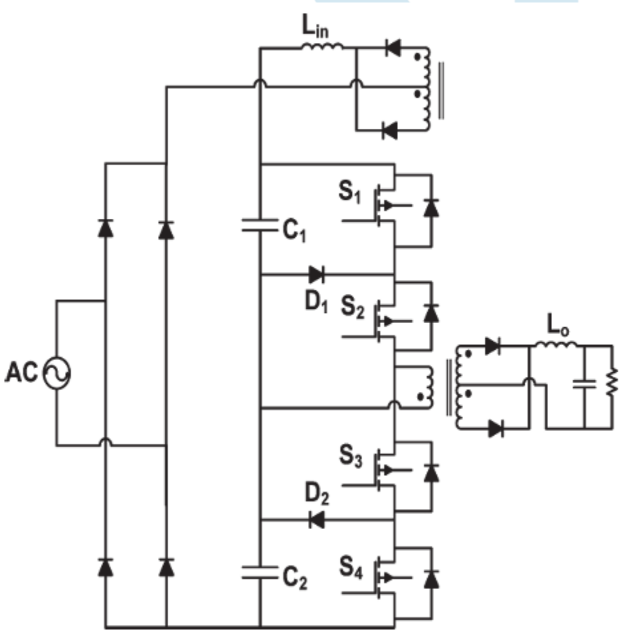


Fig. 1. Single-stage TL ac–dc converter.

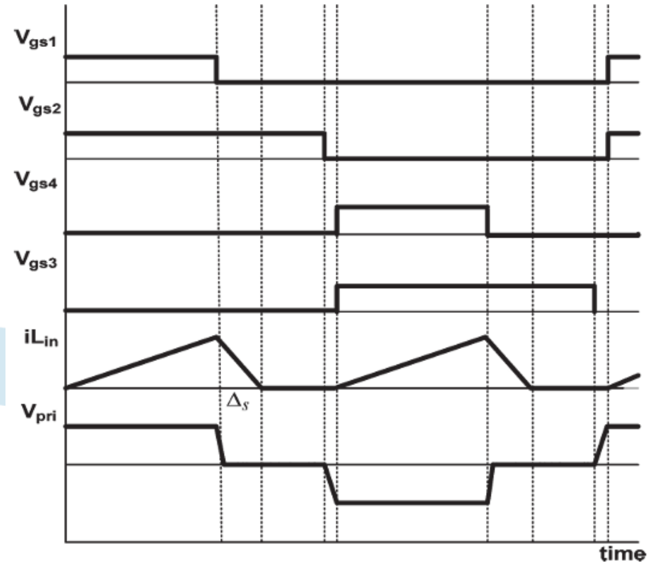


Fig. 2. Typical waveforms describing the modes of operation.

A new TL ac–dc single-stage converter that can operate with standard phase-shift PWM is proposed in this letter. In this letter, the operation of the converter is explained, and its feasibility is confirmed with experimental results obtained from a prototype converter. Finally, the efficiency of the new converter is compared with that of the converter.

## 2. PSM Technique for TL single-stage Converters

The proposed converter integrates an ac–dc boost PFC into a TL dc/dc converter. It is almost the same as the converter proposed in and with a flying capacitor between two clamping diodes. The PFC is performed by using an auxiliary winding taken from the main transformer that acts like a switch that turns on and off in an appropriate manner. Typical converter waveforms and equivalent circuit diagrams that show the converter's modes of operation with phase-shift modulation (PSM) , The diode rectifier bridge output is replaced by a rectified.

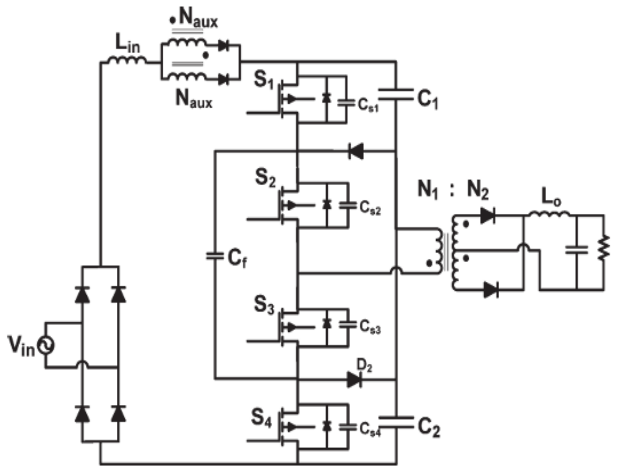


Fig. 3. Proposed single-stage TL ac–dc converter.

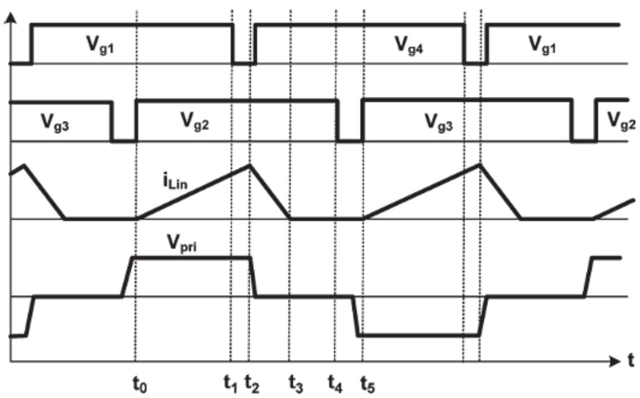


Fig. 4. Typical waveforms for the proposed converter.

**The converter has the following modes of operation.**

- $Mode\ 1\ (t_0 < t < t_1)$ : S 1 and S 2 are ON, and energy from dc bus Capacitor C1 is transferred output load. That is equal to the total dc-link capacitor voltage. the voltage across the input inductor is the rectified supply voltage, and thus, the input inductor current starts rising.
- $Mode\ 2\ (t_1 < t < t_2)$ : In this mode S 1 is OFF and S 2 is ON condition. clamps to zero. The energy stored in the input inductor during the previous mode starts to be transferred into the dc-link capacitors. This mode ends.
- $Mode\ 3\ (t_2 < t < t_3)$ : In this mode S 1 is OFF and S 2 is ON condition. The energy stored in the input inductor during Mode 1 is completely transferred into the dc-link capacitors. The amount of stored energy in the input inductor depends upon the rectified supply voltage. This mode ends when the input inductor current reaches zero. Also, during this mode, the load inductor current freewheels in the secondary of the transformer.

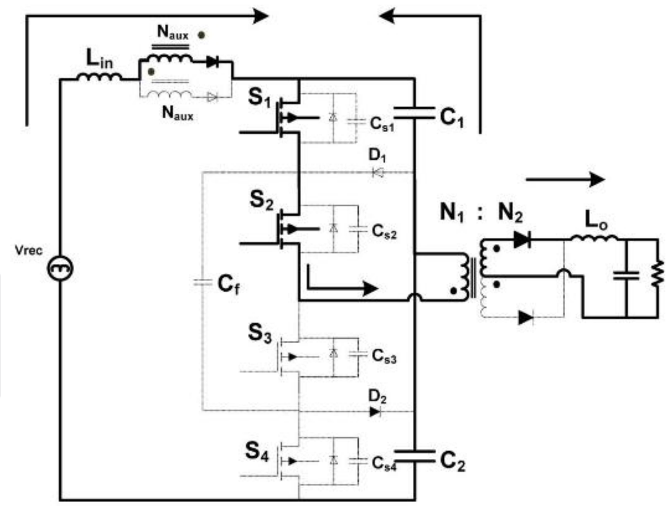


Fig 5(a) Mode of operation , mode 1 ( t0< t < t1)

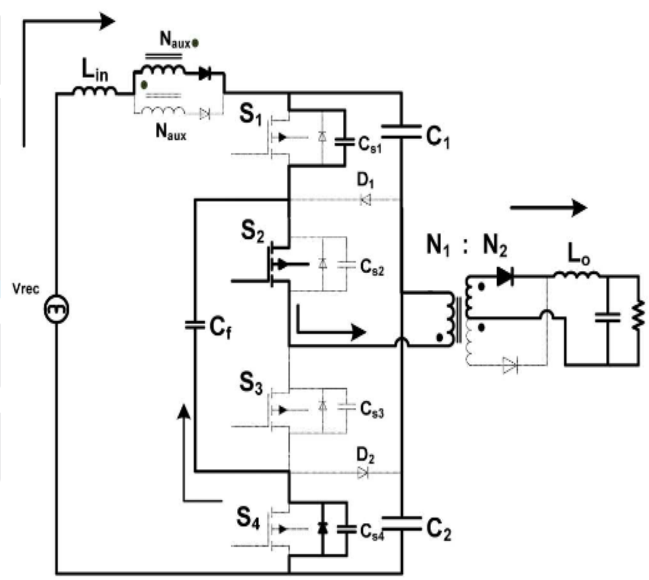


Fig 5(b) Mode of operation , mode 2 ( t1< t < t2)

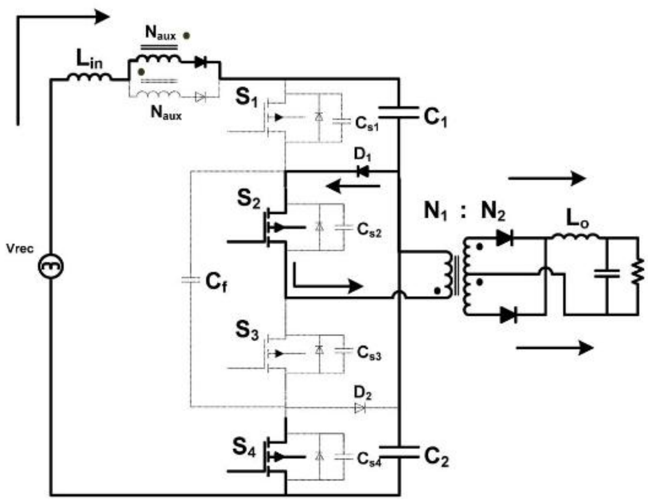


Fig 5(c) Mode of operation , mode 3 ( t2< t < t3)

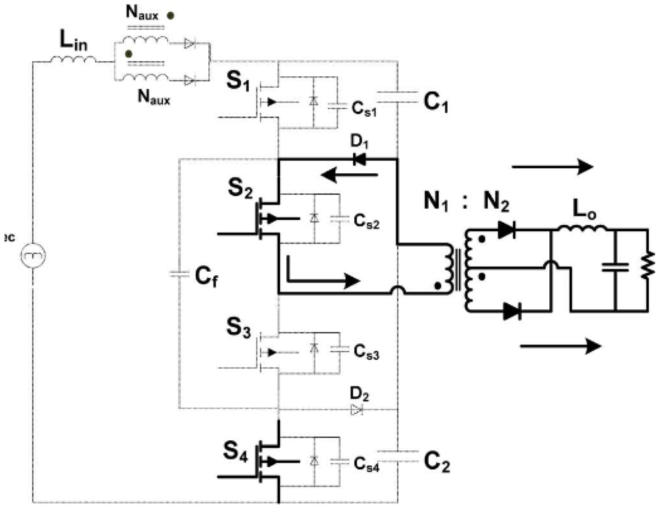


Fig 5(d) Mode of operation , mode 4 ( t3< t < t4)

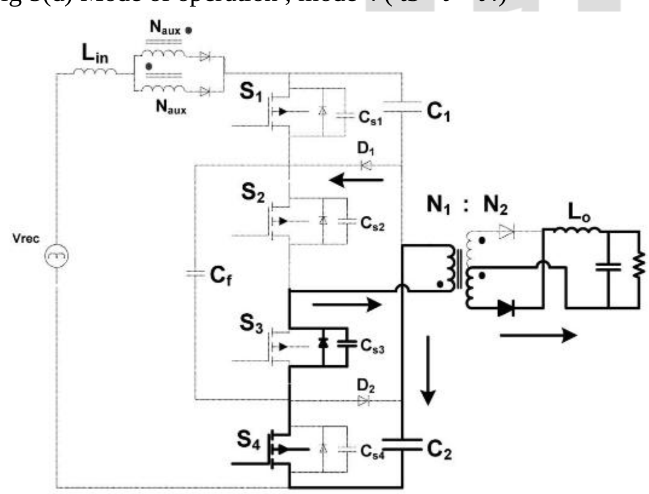


Fig 5(e) Mode of operation , mode 5 ( t4< t < t5)

- $Mode\ 4\ (t_3 < t < t_4)$ : S 1 is OFF, the primary current of the main transformer circulates through D 1 and S 2. and the load inductor current freewheels in the secondary of the transformer.
- $Mode\ 5\ (t_4 < t < t_5)$ : S1and S2 is OFF , are switched on and a symmetrical period begins. In this mode, the load inductor current continues to transfer energy from the input to the output.

## 3. Simulation Model and Results:

### 3.1 Conventional Converter Results:

A 48-Vdc 50-kHz experimental prototype of the proposed converter was built to confirm its feasibility and to compare its performance with that of the conventional TL converter .It should be noted that the converter in was implemented with the PWM method shown in Fig. 2 and with standard phase-shift PWM and not difference in efficiency was found. The new TL single-stage converter was implemented with PSM.

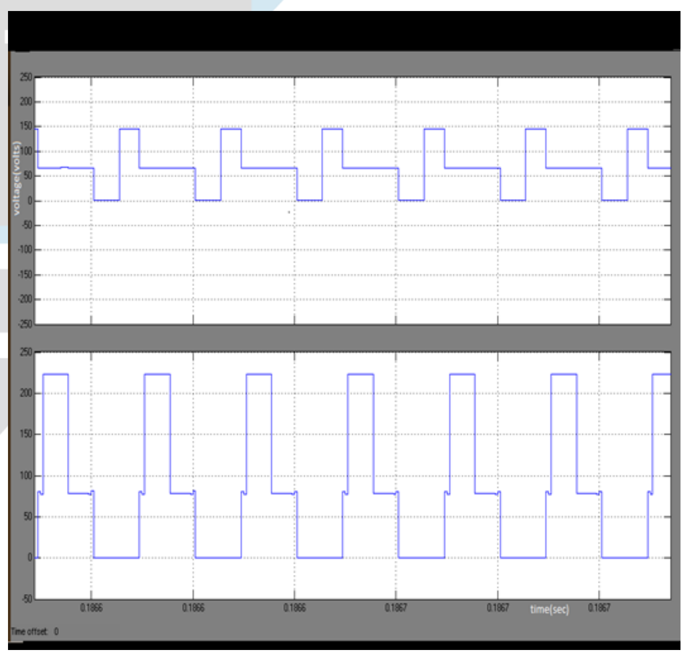


Fig.6.1 Top switch voltages $V_{ds1}$ and $V_{ds2}$

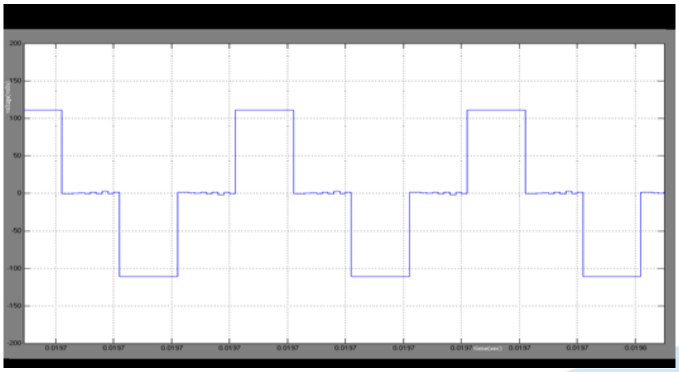

Fig.6.2 Primary voltage of transformer

## 3.2 Proposed Converter Results:

A new three level ac–dc single-stage converter that can operate with regular phase-shift PWM . The power factor correction is performed by employing an auxiliary winding taken from the primary transformer that acts sort of a switch that active and disconnect in an allotted manner.

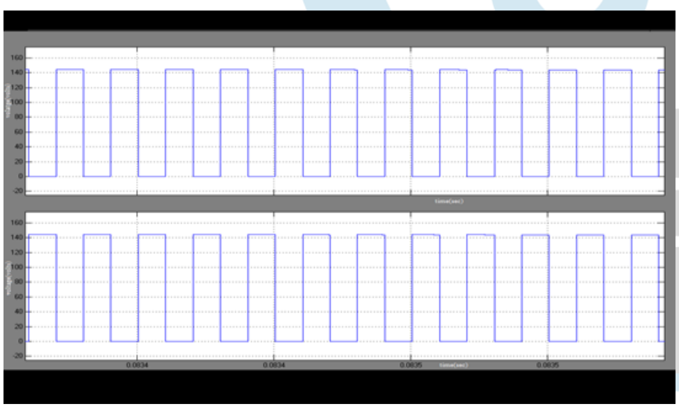

Fig.6.3 Top switch voltages $V_{ds1}$ and $V_{ds2}$

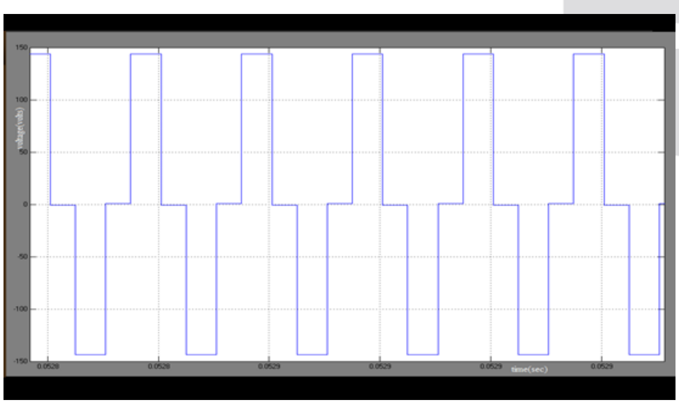

Fig.6.4 Primary voltage of transformer

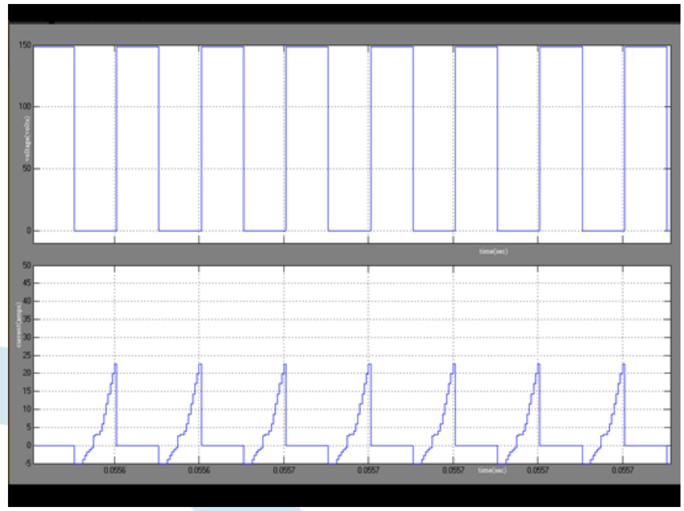

Fig 6.5 $V_{ds}$ and $I_d$ of switch $S_4$

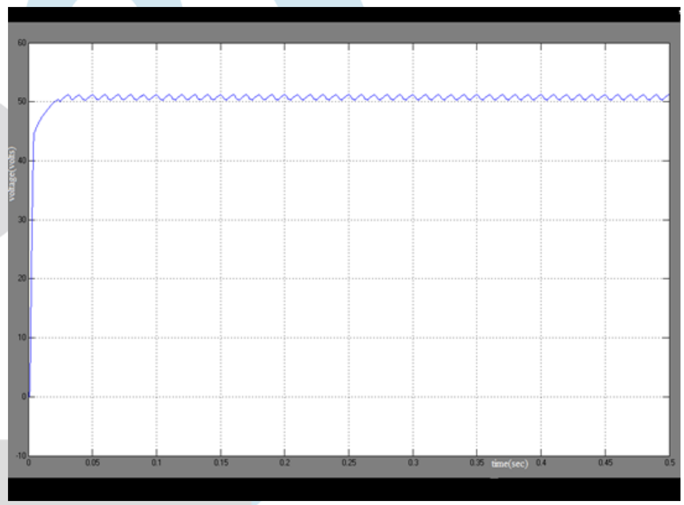

Fig.6.6 Dynamic response of dc bus capacitors

## CONCLUSION

In this project harmonic pollution and power systems caused by power converters have been of great concern. There are 3 techniques to satisfy these standards. One among them is adding passive filter components to the standard passive diode rectifier/LC filter input combination to; but the filter size bulky and heavy due to low frequency inductor and capacitor.

The second method is employing an ac-dc boost converter within the front end rectifying stage to perform active power factor correction. General two stage convertor as result of extra switching increases price and complexity. A new TL single-stage converter has been proposed in this letter. In this letter, the operation single-stage power factor corrected converter was explained, and its feasibility was confirmed with experimental results obtained from a prototype converter.

There are various publications concerning SSPFC converters, significantly for low-power ac–dc fly back and forward converters. These converters have a boost inductor attached to the input of the full-bridge circuit. Even though they will approach unity input power factor, they lack an energy-storage electrical capacitor across the primary-side dc bus which may led to in the looks of high voltage overshoots and ringing across the dc bus that limits their application.

## FUTURE SCOPE

In extension we connect a DC motor as a load to the proposed converter and observe the performance. The advantage of the proposed converter is resulting an output of 3 level which reduces stress of voltage. The proposed system is a single stage conversion where DC-DC conversion is not needed.

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