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RES Based Three Level Converter for Power Factor Improvement

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ABSTRACT

Presently world electrical energy is in sufficient due to increasing the load demand. Hence generation is a problem due to insufficient generation resources. The wind energy with a battery is a better choice for generation in present load demands. The generated energy has to be stored in battery so ac to dc converter is needed. To improve the performance of the ac–dc converter (i.e., good power factor correction, low total harmonic distortion (THD) and low dc bus voltage), two bulk storage capacitors are adopted. Its excellent line regulation capability makes the converter suitable for universal input application. The operation of the converter is discussed in the project and its various modes of operation are explained in detail. The converter is made to operate with two independent controllers an input controller that performs power factor correction and regulates the dc bus and an output controller that regulates the output voltage. They consist of an ac–dc boost pre regulator converter that shapes the input current and an isolated dc–dc full-bridge converter that converts the pre regulator output into the required dc voltage. 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. They use passive elements such as inductors and capacitors to filter low frequency input current harmonics and make the input current more sinusoidal. Two stage converters, however, require two separate switch-mode converters (each with its own controller), and thus, can be expensive. Moreover, they have poor efficiency when operating under light-load conditions as 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.

Keywords: AC–DC power conversion, single-stage power factor correction (SSPFC), three-level converters, battery based wind energy.

INTRODUCTION

Higher power ac–dc converters are required to have some sort of power factor correction (PFC) capability to comply with harmonic standards such as IEC61000-3-2. PFC methods can generally be divided into the following three categories.

1) Passive PFC Converters: They use passive elements such as inductors and capacitors to filter low frequency input current harmonics and make the input current more sinusoidal. Although these converters are simple and inexpensive, they are also heavy and bulky and are thus used in a limited number of applications.

2) Two-Stage Converters: They consist of an ac–dc boost pre regulator converter that shapes the input current and an isolated dc–dc full-bridge converter that converts the pre regulator output into the required dc voltage. Two-stage converters, however, require two separate switch-mode converters (each with its own controller), and thus, can be expensive. Moreover, they have poor efficiency when operating under light-load conditions as there are two converter stages that are operating—each with its own set o fixed losses—while a small amount of power is actually transferred to the load. These fixed losses are dominant under light-load operating conditions.

3) Single-Stage Converters: They can perform PFC/ac–dc conversion and dc–dc conversion with just a single full bridge converter. There have been numerous publications about single-stage PFC (SSPFC) converters particularly for low-power ac–dc fly back and forward converters [1]–[8].

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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 [9]–[18]. Previously proposed single-stage ac–dc full-bridge converters have the following drawbacks:

a) Some are current-fed converters with 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 [10].

b) Some are resonant converters [15], [16] 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.

c) Most are voltage-fed, 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 drawbacks 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:

i. The primary-side dc-bus voltage of the converter may become excessive under high input-line and low-output-load conditions [10]. This is because SSPFC converters are implemented with just a single controller to control the output voltage, and the dc-bus voltage left unregulated. The high dc-bus voltage results in the need for higher voltage rated devices and very large bulk capacitors for the dc bus. For example, the converter in [9] has a dc-bus voltage of 600 V.

ii. The input power factor of a single-stage voltage-fed converter is not as high as that of current-fed converters. For example, the converter proposed in [12] has an input current that is neither continuous nor discontinuous, but is "semi continuous" with a considerable amount of distortion.

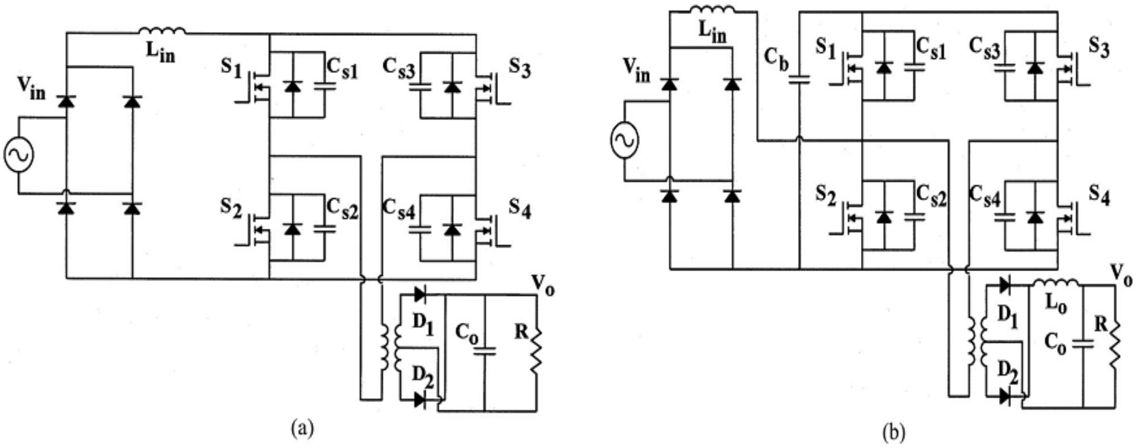

Fig1.1. *various single-stage power factor correction converters. **(a)** Boost based current-fed ac–dc PWM integrated full-bridge converter [3]. **(b)** SSPFC PWM full-bridge converter [10]*

iii. The converter is made to operate with an output inductor current that is discontinuous for all

Operation conditions or some parts of operation conditions [9], [11], [12], [18], to try to prevent the dc-bus voltage from becoming excessive; output inductor current and dc-bus voltage are related, as shown in [11]. Doing so results in the need for components that can handle high peak currents and additional output filtering to remove ripple. 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. 1.1 and three-level converters [15], [16], [19]–[22]. In the paper, a new single-stage ac–dc converter that does not have the drawbacks of previously proposed 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 feasibility of the new converter is confirmed with experimental results obtained from a prototype converter.

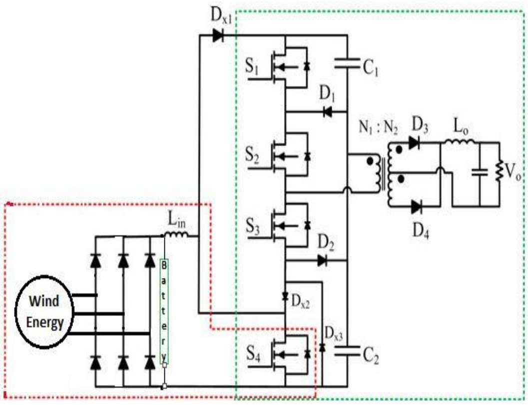

Fig1.2. *Proposed single-stage three-level converter for Wind energy*

CONTROL STRATEGY OF PROPOSED CONVERTER

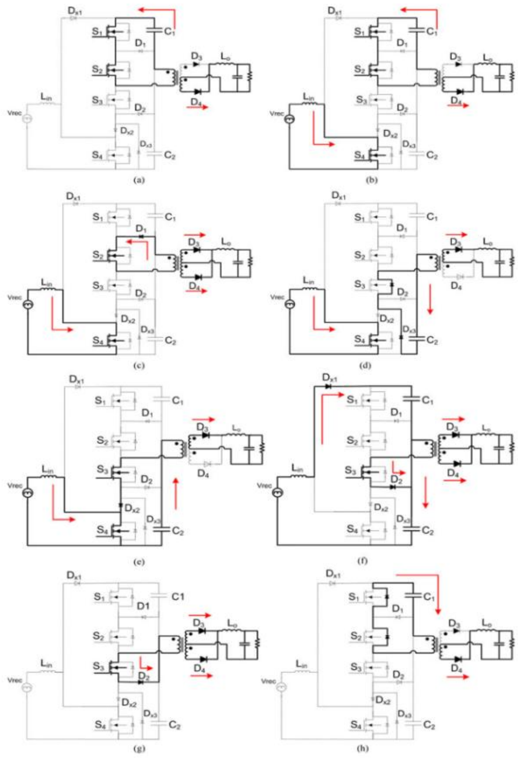

Fig2.1. *Equivalent circuits for each operation stage for the converter. (a) Mode 1(t0 <t<t1). (b) Mode 2(t1 <t<t2). (c) Mode 3(t2 <t<t3). (d) Mode 4(t3 <t<t4). (e) Mode 5(t4 <t<t5). (f) Mode 6(t5 <t<t6). (g) Mode 7(t6 <t<t7). (h) Mode 8 (t7 <t<t8)*

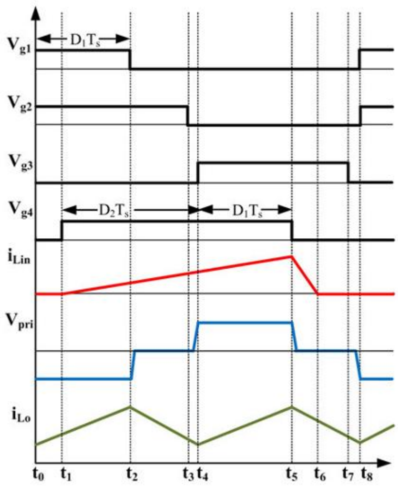

Fig2.2. *Typical waveforms describing the modes of operation*

1) Mode 1 (t0 ≤t≤t1): During this mode, switches S1and S2 are ON and energy from dc-bus capacitorC1 is transferred to the output load. In the output section, a positive voltage of (V_{pri}/n) V_O (where n is the ratio of primary to secondary transformer turns) is impressed across Lo and the current through it rises.

2) Mode 2 (t1 ≤t≤t2): In this mode, S1 andS2 remain ON andS3 turns ON. The energy from dc bus capacitor C1 is transferred to the output load. At the same time, the diode bridge output voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor rises.

3) Mode3 (t2 ≤t≤t3): In this mode, S1 andS2 remain ON andS3 turns ON. The energy from dc bus capacitor C1is transferred to the output load. At the same time, the diode bridge output voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor raises voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor rises.

4) Mode 4 (t3 ≤t≤t4): In this mode,S1 andS2 are OFF and S4 is ON. The current in the primary of the transformer charges capacitorC2 through the body diode of S3 and

Dx3.

5) Mode 5 (t4 ≤t≤t5): In this mode,S3 andS4 are ON. Energy flows from capacitorC2flows into the load while the current flowing through input inductor Lin continues to rise.

6) Mode 6 (t5 ≤t≤t6): In this mode, S4 turns off. The current in input inductor flows thorough the diodeDx1 to charge the capacitors C1 andC2. The current in the transformer primary flows thorough the S3 andD2.This mode ends when the inductor current reaches zero. Also during this mode, the load inductor current freewheels in the secondary of the transformer.

7) Mode 7 (t6 ≤t≤t7): In this mode, the load inductor current freewheels in the secondary of the transformer. This mode ends when the switchesS3turns off.

8) Mode 8 (t7 ≤t≤t8): In this mode, S3 is OFF and the current in the primary of the transformer charges capacitor C1 through the body diodes of S1 andS2. Finally, converter reenters Mode 1.

SIMULATION RESULTS

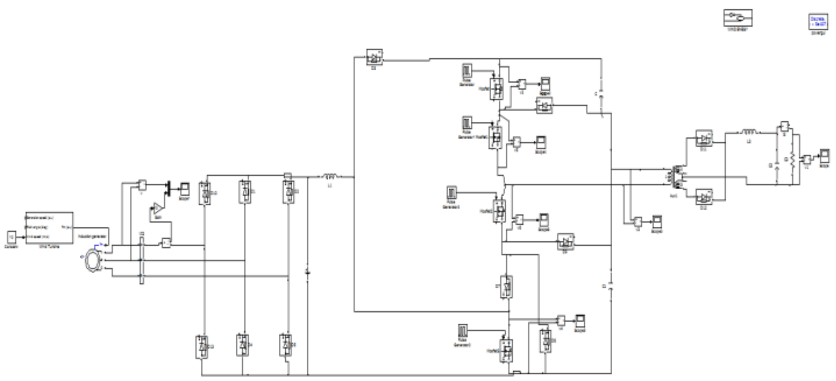

Fig3.1. *Matlab/Simulink Model of Single-Stage Three-Level Converter with battery based Wind energy using Matlab/Simulink Platform*

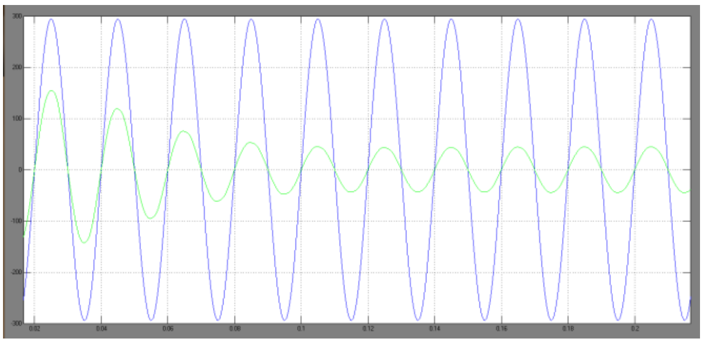

Fig3.2. *Simulated wave form of Input Current and Voltage Wave Form from wind energy*

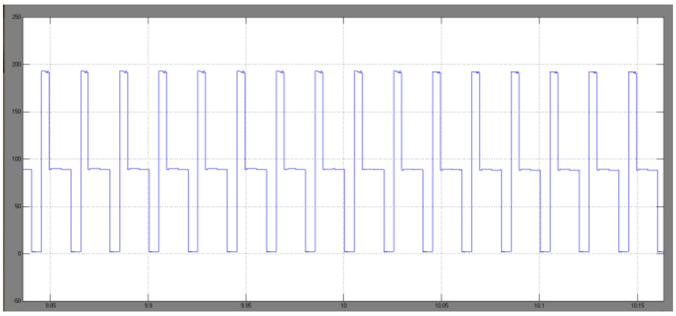

Fig3.2. *Simulated wave form of Switch Voltage S1*

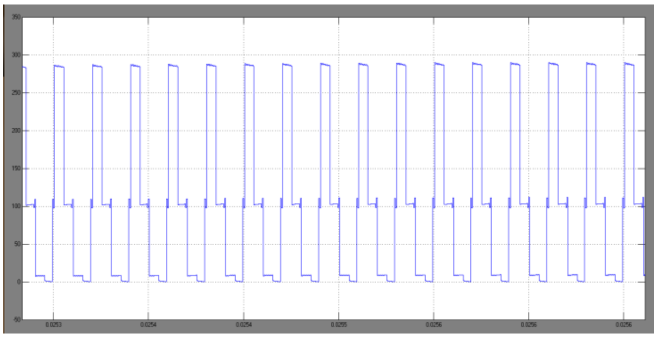

Fig3.3. *Simulated wave form of Switch Voltage S2*

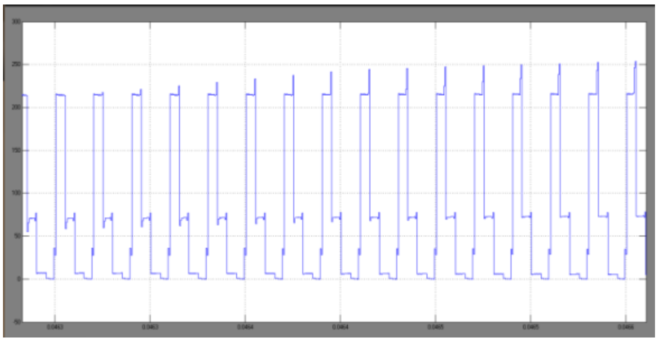

Fig3.4. *Simulated wave form of Switch Voltage S3*

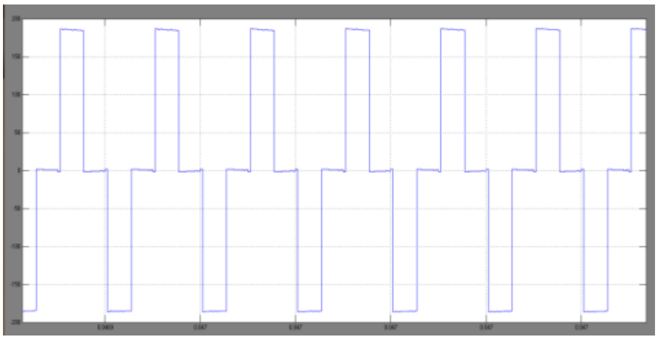

Fig3.5. *Simulated wave form of Switch Voltage S4*

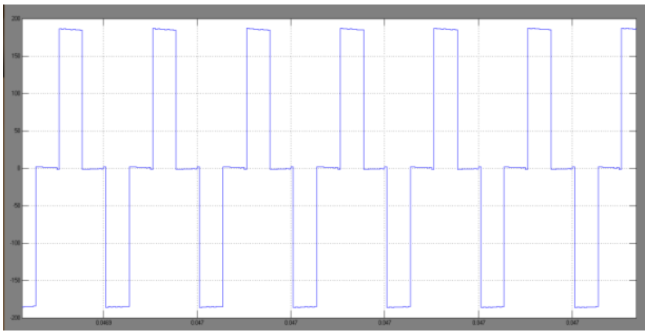

Fig3.6. *Simulated wave form of Three Level Output Voltage*

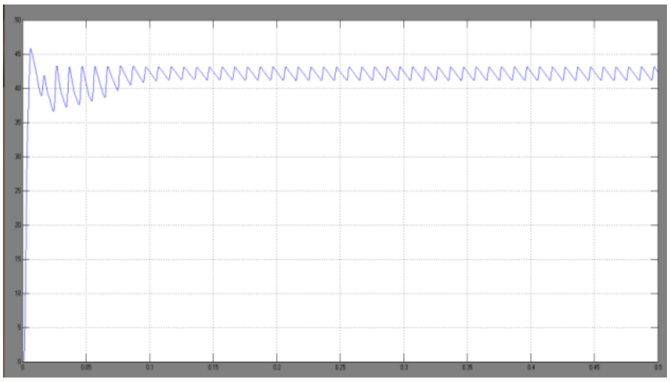

Fig3.7. *Simulated wave form of Output voltage*

CONCLUSION

In recent years, with the excessive consumption of conventional energy, the contradiction between supplication and demand and the irrational structure of world's energy as well as the environmental pollution have become increasingly apparent. It has become the key to sustainable development to reduce the consumption of traditional energy and to enhance the development and utilization of renewable energy. The wind energy with a battery is a better choice for generation in present load demands. The generated energy has to be stored in battery so ac to dc converter is needed. This converter is operated with two controllers, one controller that performs input PFC and a second controller that regulates the output voltage. The outstanding feature of this converter is that it combines the performance of two-stage converters with the reduction of cost of single-stage converters. The paper introduces the proposed converter, explains its basic operating principles and modes of operation, and discusses its design with respect to different dc-bus voltages.

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