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Review of Bidirectional Grid-Connected Single Stage Power Converter

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Abstract : A flexible and effective power conversion system that incorporates both AC-DC and DC-AC conversion capabilities into a single circuit is the Bidirectional Grid-Connected Single-Stage Power Converter. With an emphasis on bidirectional grid-connected systems, this review article offers an overview of the design, operation, and applications of single-stage power converters. The various research work of single-stage power converters are discussed in the article, along with issues including high-frequency operation, bidirectional power flow, high voltage stress, efficiency and power density, dependability, and safety. In order to assure steady and synchronized functioning with the grid, the paper also discusses challenges in bidirectional single-stage power converters linked to the grid.

Index Terms **– Bi-directional, DC-DC, AC-DC, Converter, Power, Grid-System.**

I. INTRODUCTION

A power converter is an electronic device that converts electrical power from one form to another. Power converters are used in a wide range of applications, including power supply systems, renewable energy systems, motor drives, and electric vehicles.

There are several types of power converters, including:

- AC-DC converters: These converters convert AC voltage to DC voltage. They are commonly used in power supply systems and electronic devices.
- DC-DC converters: These converters convert DC voltage from one level to another. They are used in a wide range of applications, including battery charging systems and motor drives.
- DC-AC converters: These converters convert DC voltage to AC voltage. They are used in renewable energy systems such as wind turbines and photovoltaic (PV) systems.
- AC-AC converters: These converters convert AC voltage from one frequency or phase to another. They are used in applications such as AC motor drives and voltage regulators.

Power converters typically consist of semiconductor devices such as diodes, transistors, and thyristors, which are controlled by electronic circuits to convert the electrical power from one form to another. The design and control of power converters can be complex, requiring careful consideration of factors such as efficiency, power rating, and electromagnetic compatibility (EMC) to ensure safe and reliable operation.

A bidirectional grid-connected single-stage power converter is a type of power electronic converter that can transfer power bidirectionally between an AC grid and a DC source or load. This converter is typically used in renewable energy systems such as wind turbines or photovoltaic (PV) systems, where the power output is DC and needs to be converted to AC for grid connection or vice versa.

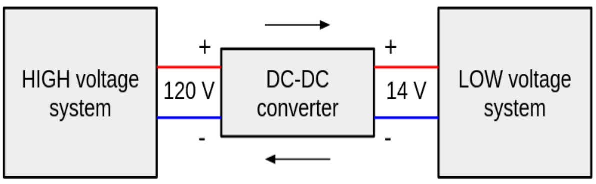

Figure 1: Basic of DC-DC Converter

The one-stage power converter streamlines the system's design by incorporating both the AC-DC and DC-AC conversion processes into a single circuit. The converter's bidirectional characteristic enables it to function in both grid-feeding and grid-forming modes.

The converter generally comprises of a high-frequency transformer that separates the AC side from the DC side and a power converter circuit that performs the AC-DC and DC-AC conversions using semiconductors like MOSFETs, IGBTs, or diodes. To ensure the converter operates safely and effectively, the converter circuit also has control and protection circuits.

In comparison to conventional two-stage power conversion systems, the bidirectional grid-connected single-stage power converter provides a number of benefits, including greater efficiency, cheaper cost, and less complexity. Nevertheless, because to the bidirectional power flow and the need for quick and precise control of the output voltage and current to guarantee stable operation and grid synchronization, the design and management of the converter might be difficult.

II. BACKGROUND

N. Z. Kashani et al.,[1] An unidirectional grid-connected single-stage converter that is presented in this work comprises of a power conversion stage that is a bidirectional DC-DC converter in addition to an unfolding circuit. This converter is designed to be bidirectional. The low DC voltage may be turned into a rectified sinusoidal voltage by modifying the Pulse Width Modulation (PWM) of the DC-DC converter. The unfolding circuit, which functions at the frequency of the grid, is responsible for unfolding and folding the rectified sinusoidal waveform and establishing a current channel to the grid. As a result of the minimal switching loss it incurs, its status as a power conversion step is not highly regarded. To ensure that the mathematical analysis is accurate, the computer simulations are carried out in a MATLAB/Simulink environment. The converter that is being suggested has an output current ripple of less than 1%. The suggested converter was able to attain a switch usage factor that was 12% greater than that of a state-of-the-art converter that operated on a similar basis.

M. R. Reddy et al.,[2] In this work, a unique modulation strategy is proposed for use with a single-phase, single-stage, high gain, six-switch, four-port (6S4P) converter. The low voltage DC port is the first of the four ports. 2) a port for high voltage DC current, followed by 3) an AC port and 4) two AC ports. Both a novel Rectified Inverse Level-shifted Sinusoidal Pulse Width Modulation (RILSPWM) scheme and a Phase-shifted Rectified Level-shifted Sinusoidal Pulse Width Modulation (PRLSPWM) scheme are proposed and used in the proposed converter in order to ensure that it operates as efficiently as possible. The suggested converter, in conjunction with the modulation method, is capable of producing a large voltage gain at both the DC and AC ports. Moreover, the AC ports are run at varying magnitudes and frequencies.

A. Singh et al., [3] This research proposes an isolated single-stage battery charger for light electric vehicles (LEVs) that has a good power quality and is based on an AC-DC buck-boost converter that has a high step-down gain. The charger that has been presented has several advantages over the traditional two-stage charger, some of which are a reduction in the overall component count, a reduction in cost and size, the elimination of a large DC Link capacitor, a reduction in the amount of effort required to control the charger, and improved dynamic voltage regulation. By designing the converter to operate in discontinuous conduction mode, the size of the charger as well as its price may be reduced even more (DCM). Using the converter in its bridgeless version results in a considerable reduction in the conduction losses that are associated with the full bridge diode rectifier. This results in an improvement in the overall efficiency of the charger that is being offered (DBR). This research evaluates the feasibility of the charger and its performance during both steady and dynamic states by simulating a 450 W charger. It does this by looking at the charger's performance.

A. Chambayil et al.,[4] In this study, a single-stage three-phase bidirectional ac-dc dual active bridge (DAB) converter is proposed as a means of connecting battery energy storage devices to the ac grid. The converter is equipped with multiphase boost interfaces on both the ac side and the dc side of the device. The interleaved functioning of the multiphase boost units prevents switching frequency ripples from arising in the input and output currents. This removes the need for filtering on both the input and output sides of the device. Interleaved half-bridge converters are used on the alternating current (ac) side of the converter. The converter obtains sinusoidal currents from the ac grid while maintaining unity power factor by running the interleaved converters in sinusoidal pulse width modulation. It is used for the purpose of connecting with the high-frequency transformer in order to facilitate the power flow of the dual active bridge. The dc side of the converter is made up of three parallel boost converters that are linked to one another. These boost converters each include three switching legs, three boost inductors, and a common dc bus. On the dc side, the dc bus is formed by two parallel series of capacitors that are linked to one another.

S. Chattopadhyay et al., [5] A single-phase, single-stage, low-frequency ac to high-frequency ac converter for induction cooking applications is proposed by this body of work. Active power factor adjustment is possible at the input of the converter, and high-frequency resonant voltage may be produced at the output of the device. A resonant output filter is supplied for the purpose of filtering the high-frequency current that is drawn by the load so that the converter is relieved of the responsibility of carrying this current. For the purpose of producing gate pulses, the converter makes use of a process known as sinusoidal pulse width modulation. This article explains the control structure of the converter that is used for induction cooktop applications. The viability of the suggested method was tested using a two-stove, two-kilowatt induction cooker converter. The experimental results gained validated the system's potential.

A. D. Kumar et al.,[6] The following is a demonstration of a charger setup for low-voltage electric cars that is derived from a modified Cuk converter (LVEVs). This study presents a topology that is a modification of the typical Cuk-based converter. It uses a construction that is fully bridgeless and has the capacity to deliver a large voltage step-down gain in a single stage between the supply AC voltage mains and the battery side. The charger that is shown in this study has strong input side performance, with a high power factor and minimal input current harmonic distortions. Moreover, it is able to maintain a decent charging profile at the battery end of the charging process. Last but not least, the converter is simulated using a battery load of 450 watts, 48 volts, and 100 ampere-hours with a device switching frequency of 20 kilohertz, and the outcomes of the simulation are reported in this work.

A. R. Kota et al.,[7] A means for methodically building the Hybrid sensitive switching Mode gameplay mechanic. In this work, PWM full crossed over DC to DC (IBB) converters are presented. With the proposed group of converters, it is feasible to achieve single-stage power change, zero-voltage and zero current, as well as high-effectiveness execution. Adjustments to the delicate switching procedure of the main switches may be made according to the specific information and yield circumstances in order to obtain the maximum possible efficacy of the framework. Since there is no demand for light burden activity in the zero-voltage exchanging (ZVS) mode, the mood killer exchanging calamity may also be simplified in this mode. This mode is referred to as "ZVS." The extra conduction loss is maintained to a minimal by using low-voltage rated MOSFETs and diodes that have improved exchange and conduction exhibitions. This keeps the additional conduction loss from occurring.

L. Mitra et al.,[8] Comparative analysis of two distinct boost converter topologies is the focus of this article. Because of their large step-up voltages, these converters may be used with renewable energy systems such as photovoltaic cells, fuel cells, and electric cars. Applications requiring high voltage and high power may benefit from the usage of this boost converter. Since both converters make use of high frequency transformers, they are suitable for use in grid-connected systems as well as applications that need a great deal of power. The multi-stage design of these converters makes MOSFET selection simple and results in a reduction in the component size required for filtering. There is a decrease in the current ratings of the switches and volume of the components when using multi-stage converters rather than single-stage converters since they are operated at a very high switching frequency. This makes multi-stage converters preferable to single-stage converters. Because of the increased efficiency of the transformer, its size has been reduced as a result.

U. K. Kalla et al.,[9] The converter operates on a single switch and provides low voltage stress between the diodes and switch, which results in a simpler and more efficient operation. Since the converter receives a continuous input current from the source, it is appropriate for use with fuel cells and batteries. This article presents a two-stage power conversion for the optimal operation of the BLDC speed control drive. The first stage of the power conversion is a dc-dc converter to achieve an optimal DC-link voltage level, and the second stage is an inverter to achieve an effective 120° mode of commutation. Both stages of the power conversion are necessary for the optimal operation of the BLDC speed control drive. The suggested system is simulated using MATLAB-Simulink, and the performance results that are produced from the simulation are shown. The purpose of this is to demonstrate and validate that the proposed scheme is effective.

S. Khatroth et al., [10] Induction cooking (IC) applications are shown using a single-stage AC-AC resonant converter, which is presented in this study. Power factor correction, boost operation, and independent load power regulation are all components of the work that is being suggested. For the purpose of independent power control, this study makes use of the cyclic control approach. Three different loads are being powered by the inverter's three different legs. The ratio of switching devices to loads is always two to one. It is possible to produce ZVS operation for load variations across a greater range, and a high converter may be attained. The method that was created consists of fewer components and, on average, employs one leg for each weight. In addition to that, it is expandable so that it can support more than three loads.

III. SINGLE-STAGE POWER CONVERTER

A single-stage power converter is a type of power electronic converter that combines both the AC-DC and DC-AC conversion functions into a single circuit. Single-stage power converters are used in a variety of applications, including motor drives, renewable energy systems, and power supply systems.

The main advantage of single-stage power converters is their simplicity and reduced number of components compared to traditional two-stage power conversion systems. This can result in lower cost, reduced weight, and increased efficiency.

Single-stage power converters can be classified into two categories: isolated and non-isolated converters.

1. Isolated single-stage power converters use a high-frequency transformer to isolate the DC side from the AC side. The transformer allows for galvanic isolation, which provides protection against voltage transients and improves safety.

2. Non-isolated single-stage power converters do not use a transformer and have a direct connection between the AC and DC sides. Non-isolated converters are simpler and more compact, but they do not provide galvanic isolation and can be less safe.

IV. CHALLENGES

While single-stage power converters offer several advantages over traditional two-stage power conversion systems, they also pose some challenges in their design and operation. Some of the challenges in single-stage power converters are:

1. High-frequency operation: Single-stage power converters operate at high frequencies, typically in the range of several tens or hundreds of kilohertz. High-frequency operation can cause electromagnetic interference (EMI) issues and require careful attention to the layout and shielding of the circuit.

2. Bidirectional power flow: Some single-stage power converters can transfer power bidirectionally between the AC grid and the DC source or load. Bidirectional power flow requires fast and accurate control of the output voltage and current to ensure stable operation and grid synchronization.

3. High voltage stress: Single-stage power converters use semiconductor devices such as MOSFETs and IGBTs, which are subjected to high voltage and current stresses during operation. This can cause thermal and electrical stresses and require careful thermal management and protection circuits.

4. Efficiency and power density: Single-stage power converters must achieve high efficiency and power density to be competitive with traditional two-stage power conversion systems. This requires careful selection of the semiconductor devices, optimal circuit design, and advanced control algorithms.

5. Reliability and safety: Single-stage power converters must be designed for reliable and safe operation under a wide range of operating conditions. This requires careful attention to the selection and testing of components, as well as the design of protection and fault detection circuits.

V. CONCLUSION

The article concludes that the Bidirectional Grid-Connected Single-Stage Power Converter is a promising technology that offers several advantages over traditional two-stage power conversion systems. However, the design and operation of single-stage power converters pose several challenges that require careful consideration and optimization of the circuit design, semiconductor devices, control algorithms, thermal management, and protection circuits. Further research and development in this area can lead to improved performance, increased functionality, and expanded applications of single-stage power converters. The article provides a valuable resource for researchers, engineers, and practitioners interested in the design and application of bidirectional grid-connected single-stage power converters.

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