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A Review of Bidirectional Power Conversion Converter for Power System Applications

Amit Ranjan[1], Dr. Ashok Kumar Jhala[2]

[1]*Research Scholar, Department of Electrical and Electronics Engineering, Bhabha University, Bhopal, India*
[2]*Associate Professor, Department of Electrical and Electronics Engineering, Bhabha University, Bhopal, India*

***Abstract*— The demand for safe and reliable electricity increases, our infrastructure continues to evolve and innovate in order to accommodate such growth. The benefits of energy storage can span power generation, through transmission and distribution, and all the way to users. An energy storage system is indispensable for compensation of the active-power fluctuation; it can mitigate the disturbance and maintain the stability of voltage and frequency. Power conversion system (PCS), as an interface between storage system and public grid, plays a great role in achieving the power transfer between storage system and public grid. This paper summarize the various research based on power conversion converter for battery energy storage systems current topologies and the control strategies commonly used in engineering under different working situations and requirements, and analyze their differences and characters, which will helps in choosing the PCS structures and control strategies.**

***Keywords*— Power, Conversion, Converter, Energy, Battery, Storage.**

I. INTRODUCTION

Battery energy storage system (BESS) has been used for some decades in isolated areas, especially in order to supply energy or meet some service demand. There has been a revolution in electricity generation. Today, solar and wind electricity generation, among other alternatives, account for a significant part of the electric power generation matrix all around the world. However, in this scenario of high level of renewable energy, BESS plays a key role in the efforts to combine a sustainable energy source with a reliable dispatched load and mitigates the impacts of the intermittent sources. Therefore, the installation of BESS has increased throughout the world in recent years. Despite their benefits, the implementation of such systems faces considerable challenges.

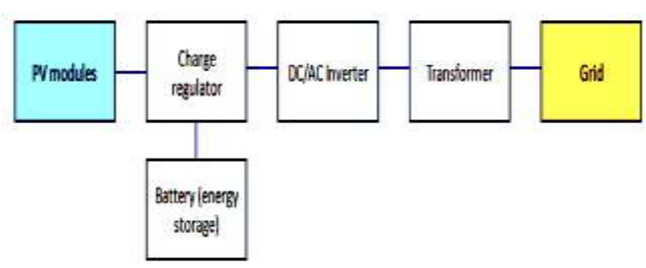

Figure 1: Block diagram of battery energy storage system

Energy storage system consists of two parts, storage facility and PCS. PCS, the interface between storage facility and micro grid(utility grid), operates the function of transferring and swapping energy between the storage system and the micro-grid bidirectionally. The structure and control strategy are significant for the stability, efficiency and performance of the PCS. This paper summarizes the commonly used topology structures, and analyzes their differences and characters. Then the control strategy is presented and summarized.

With the rapid development of global economy, the global electricity consumption surges which give rise to the serious power supply shortage. Renewable energy sources such as wind turbine generators and photovoltaics provide a new way to resolve the problem. However, the distributed power such as photovoltaic power and wind power are intermittent and produce fluctuating active power. Interconnecting these intermittent sources to the utility grid at a large scale may affect the voltage and frequency control of the grid, and may lead to severe power quality issues. Therefore, Energy storage system is very important for the micro-grid, it can store the excess power from the grid when the power supply is greater than the power consumption.

On the other hand, it releases the shortage of power to the grid when the generation system produces a smaller power. The energy storage system brings a significant enhancement in power quality, stability and reliability to the grid. Therefore, the energy storage system is more and more widely used in distributed generation system and micro grid.

II. Literature Survey

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 creating a current route that leads to the grid.

M. R. Reddy et al.,[2] presented 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. The unique Rectified Inverse Level-shifted Sinusoidal Pulse Width Modulation (RILSPWM) and Phase-shifted Rectified Level-shifted Sinusoidal Pulse Width Modulation (PRLSPWM) methods are suggested and used in the proposed converter so that it may operate efficiently.

A. Singh et al., [3] presented 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 shown has various benefits over the traditional two-stage charger, some of which include a decrease in the total component count, a reduction in cost and space, the removal of a huge DC Link capacitor, a reduction in the amount of effort required to manage the charger, and improved dynamic voltage regulation.

A. Chambayil et al.,[4] presented, 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.

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.

A. D. Kumar et al.,[6] presented a demonstration of a charger configuration for low-voltage electric cars (LVEVs), which is based on a modified version of the Cuk converter. 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. In addition, the intermediate inductors in the presented charger configuration have been designed for discontinuous inductor current mode. This helps in reducing the size of the magnetic components, facilitates inherent power factor correction at the input side, and reduces the switching losses that are incurred in the conducting devices.

A. R. Kota et al.,[7] presented, 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. The turn-ON and turn-OFF exchanging challenges may be eased because the sensitive turning states of the turn-ON and turn-OFF moments are very much dissociated in the zero-voltage and zero-current exchanging (ZVZCS) mode.

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.

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Because 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.

U. K. Kalla et al.,[9] presented a two-stage power conversion for the optimal operating of the BLDC speed control drive. The first stage of the power conversion is a dc-dc converter to generate 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 functioning of the BLDC speed control drive.

S. Khatroth et al.,[10] presented, 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.

III. VARIOUS POWER CONVERSION CONVERTERS

A. Topologies and Control Strategies of PCS

The storage facility in this paper is referred to storage battery units. PCS is a power electronic converter in nature used to regulate the power transfer between the storage facility and micro-grid. Figure below show the structure of the whole energy storage system.

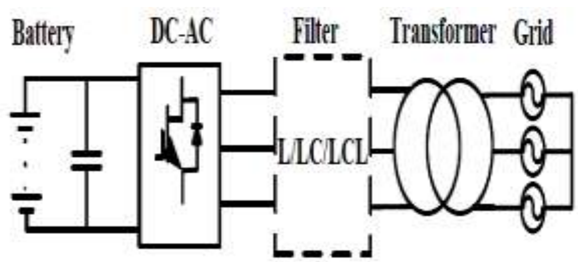

Figure 2: Topology of single-stage power conversion system

Structure of energy storage power conversion system PCS has many topological structures, the commonly used structures such as single-stage PCS, two-stage PCS and cascaded PCS will be presented.

B. Single-stage PCS

Figure 2 shows the single-stage PCS topology. From the figure we can conclude that the PCS is essentially a bidirectional dc-ac converter.

This converter can not only absorb superfluous energy from the grid and store the power in battery units, but also release energy stored in the battery banks to the grid and convert the dc voltage to ac voltage connected to the grid in order to keep the balance of the grid. Moreover, a filter could be installed in the output side of the battery unit to filter out the harmonics and mitigate the ripple in the currents injected into the grid. Topology of single-stage power conversion system The prominent advantages of single stage PCS are the simple circuit structure, relatively simple control method, and less switch quantity which means less losses.

C. Two-stage PCS

The dc-dc converter is mainly used for boosting or bucking the dc voltage and provides a stable dc voltage. DC-AC converter work in the state of rectification mode when the battery units release power and convert the ac voltage of the grid to dc voltage. This dc voltage will be regulated by the dc-dc converter and stored in the battery. When the battery release energy, the output dc voltage of the battery units is boosted by dc-dc converter and provide suitable input dc voltage to dc-ac converter. At last output a appropriate ac voltage required by utility grid. L/LC/LCL Battery DC-DC DC-AC Filter Transformer Grid.

In the practical application, bidirectional dc-dc converter is categorized by isolated dc-dc converter and non-isolated converter. The difference between the two kinds of converters is whether there is a high frequency isolation transformer. introduced in detail the traditional non-isolated dc-dc converters such as bidirectional dc-dc converter, bidirectional Boost/Buck converters, bidirectional Cuk converters and bidirectional Sepic converters.

D. Cascade multilevel PCS

H-bridge converter is increasingly widely used in practical application. To reduce the batteries nominal voltage, the number of series connected storage cells can be distributed in a number of converter cells making use of the cascaded H-bridge converter. This cascaded H-bridge structure allows direct connection to a medium-voltage grid with less voltage/current harmonics without bring any increase in voltage rating to individual switching devices[8]. H-bridge converter has many advantages. Firstly, multilevel output could upgrade the current quality injected to the grid. Secondly, cascaded structure reduce the voltage in each 264 converter cells and bring a reduction to switch losses, and have a equivalent switching frequency under the fundamental switching frequency operating condition.

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Moreover, it also has a easy and flexible extension capability because of the modular packing of the converter. In recent years, there are few researches on control strategy of cascaded H-bridge PCS. Power conversion is converting electric energy from one form to another such as converting between AC and DC; or changing the voltage or frequency; or some combination of these. A power converter is an electrical or electro-mechanical device for converting electrical energy. This could be as simple as a transformer to change the voltage of AC power, but also includes far more complex systems. The term can also refer to a class of electrical machinery that is used to convert one frequency of alternating current into another frequency.

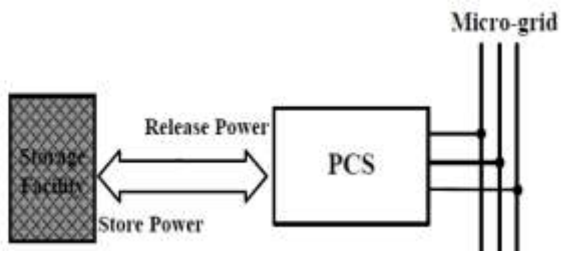

Figure 3: Structure of energy storage power conversion system

The block diagram of a power electronic converter is shown in figure above. It consist of an electrical energy source, power electronic circuit, a control circuit and an electric load. This converter changes one form of electrical energy to other form of electrical energy.

The power electronic circuit consists of both power part and control part. Power part transfers the energy from source to load and it consists of power electronic switches (SCR or TRIAC), transformers, electric choke, capacitors, fuses and sometimes resistors.

IV. CONCLUSION

With the continuous progress of batter technology and power electronics technology, the structure of the PCS will be revised and improved. In the current practical application, single-stage PCS will be commonly and extensively used in the small and medium power application considering the efficiency and cost. While in high power application, the modular cascaded H-bridge PCS is the most suitable choice. The new structure develops towards a direction of less losses, higher reliability, higher efficient cost and higher degree of modularity. Moreover, as the control strategy is becoming more and more mature, PCS could flexibly adopt different control strategies according to different working modes or control targets.

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