Advanced Science and Technology Letters
Vol.82 (SoftTech 2015), pp.111-117
http://dx.doi.org/10.14257/astl.2015.82.21

Research and Design for a New Storage Type Converter

Yang Gao, Aoran Xu, Liu Zhang, Gang Wang, Di Bai, Yi Zhao

Shenyang Institute of Engineering, Shenyang, China.
Email: xuaoran@163.com

Abstract. In the micro-grid, power storage converter is played as a interface between the battery pack and grid electricity storage device, to achieve a two-way exchange of energy. In this paper, the research and development of power storage converter can realize multiple sets of independent control of the battery, flexible configuration of the system capacity and flexible cutting of the battery pack. Structural design uses multi-level topology. It contains 15 non-isolated half-bridge parallel bi-directional DC / DC converter. Control strategy designed to be grid inverter adopts SVPWM control technology. DC / DC converter designed to improve the droop control strategy based on environmental design. The high-power energy storage converter product this paper designed have completed the charge and discharge related droop control and Full power grid experiment.

Keywords: Battery energy storage system, Droop control, DC / DC converter.

1 Introduction

With the great development of new energy industry, now there have been some new problems and challenges highlighted in the new energy generation and net consumptive problems. Wind, solar energy is an intermittent presence of random, intermittent characteristics, resulting in artificially difficult to accurately predict power, winds power, photovoltaic power plants is difficult to provide continuous and stable power [1-7]. In wind farms, photovoltaic power plants around supporting the energy storage system can be added to balance wind power, active power output of photovoltaic power fluctuations, the power output of new energy curve as expected output, so you can minimize the difficulty of grid scheduling for more new energy generation and networks to create conditions for the smooth [8-9].

With the rise of micro-grid technologies, whether the Micro-grid system has enough capacity to accept a variety of disturbed power is the decisive factor of system interconnection efficiency. As energy storage system of the micro grid, batteries play an important role in micro grid interconnection technology. Battery exchanges energy with power grid by energy conversion system, and stored energy or release energy in accordance with the actual situation. Energy conversion system plays a role as a connection between the battery and power grids as the interface to achieve the two-way exchange of energy between the battery and power grid. The essence of the

ISSN: 2287-1233 ASTL

energy conversion system is the storage of high-power converter. The energy storage converter this paper researched and developed can realize separate control of multiple sets of batteries and freely configurable switching capacity. DC / DC converter using droop control had overcome the uncontrollable problem of unable to create intermediate DC voltage and charge-discharge voltage when the off-grid work in the conventional constant-current control and fixed DC bus voltage control. Eventually developed products verified the rationality of the design by droop control the charging and discharging experiments and grid efficiency experiment.

2 High-power energy storage converter topologies

Single-stage type storage converter can control the entire battery charge / discharge current of the total, the control unit can not be set battery charge / discharge current due to the internal resistance of the battery between the groups do not completely equal, the entire battery charging / total current discharge is unevenly distributed between the respective battery groups, causing the flow characteristics are not good between the battery pack.

Since the capacity of the single stage type energy storage converter topology cannot be changed at any time, the energy storage system output voltage is unstable and poor flow characteristics, as a part of the light complementary storage system.

The energy storage this paper researched and developed need to realize the multiple sets of independent control of the battery, flexible configuration of the system capacity and flexible cutting of the battery pack, so storage converter designed for multi-level topology. The storage converter contains 15 parallel bi-directional DC/DC converters and a PWM converter. Compared with only a DC / AC aspects of a single-stage topology, the multilevel topology has one more DC/DC link. Multi-stage type storage converter first let the DC power the battery produced go through the DC/DC converter to boost the voltage, and then supply PWM converter as a DC-side input voltage, input power after the inverter. Otherwise, the AC power grid generated will be rectified to a DC voltage through PWM converter, then buck through the DC/DC converter to get the charging voltage of the battery. This is designed to make the working voltage through the DC/DC conversion have a wide range of operation.

The advantage of this topology is that the battery pack voltage operating range is wider. After the battery voltage DC / DC converter to convert the voltage rating of the battery required to reduce the operating voltage range, the battery can achieve a wide range of operation. Compared with the single-stage type, the presence of multi-stage topologies weaknesses, including: a converter the increased DC / DC link, the energy conversion efficiency of the entire system is reduced; the same time as an increase in the device, consider the DC / DC coordinate converter, PWM rectifier fit between problem, increase the complexity of the control.

In the multi-stage topology, based DC / DC converter topology types can be divided into non-isolated topology and isolated topologies two categories. Isolated topology contains high frequency transformer, DC / DC converter through step-up transformer, and can achieve electrical isolation between the battery pack and the power grid, but due to the introduction of high-frequency transformer reduces the energy conversion efficiency, while increasing converter design cost. Isolated bidirectional DC / DC converter including topology, and an organic combination of these topologies Forward, fly back, push-pull, bridge and so on. Isolated topologies each have their own characteristics, and have different scope.

Non-isolated since no high-frequency transformer, its structure is simple, less desired device, small size, low cost, high reliability and high overall energy conversion efficiency, control is relatively simple. However, their existence ratio is not too large, the battery pack can not be electrically isolated from the grid, particularly when the grid is a problem that may interfere with cell passages, is not conducive to stable operation of the safety of the battery pack. Non-isolated bidirectional DC / DC converters typically include half-bridge, full-bridge type, three main cascade topology.

The DC / DC converter this paper researched and developed adopts non-isolated topology and contains high frequency transformer. DC / DC converter boosts the voltage through transformer and can realize the electrical isolation between the battery and power grid at the same time. Each set of batteries connected to the DC side in the middle by a bi-directional DC / DC converter respectively, then filtered through DC / DC links and connected to the grid after the transformer. This topology has some advantages:

(1) Can access multiple sets of batteries. Each battery pack can realize the multiple set of battery charge / discharge control independently through independent DC / DC link control.

(2) The battery pack has wide working voltage range.

(3) Circulation between the battery pack can be avoided.

(4) Can realize the flexible configuration of the entire battery energy storage system capacity and flexible switching of the battery pack.

3 High-power energy storage converter control strategy

Storage converter control strategies for energy storage converter control method of each part, we study the constant current control, given the DC bus voltage control, droop control three control strategies, and finally selected the droop control strategy. Battery energy storage system consists of DC / DC control and DC / AC controls two parts. The need for both control methods were designed to coordinate both control objectives through the upper controller, so that the two good cooperation in order to implement the entire storage converter control strategy.

Grid converter (three-phase VSR) the main control objectives are twofold: First, to ensure the stability of the intermediate DC voltage, DC link voltage stability is a prerequisite for PWM converter to work properly, which is achieved by controlling the input current of ; the second is to ensure good input specific, nearly sinusoidal input current that is small harmonic content to meet the power factor requirements.

At present, the most commonly used three-phase VSR control strategy is based on the dual-loop control coordinate transformation theory, methods based on different coordinate directional control strategies can be divided into grid-side voltage and based on virtual flux based control strategy. Network-based control strategy to estimate and side voltage grid voltage detection is based, including voltage-oriented control (Voltage oriented control, VOC) and Direct Power Control (Direct power control, DPC).

Directional control voltage dual closed-loop structure of the intermediate DC voltage outer ring, the inner side of the current network to the grid voltage space vector direction as a reference, and directional control of the current direction, the closed-loop output can and space vector pulse width modulation (SVPWM) interface, after the conversion of the pulse width modulation pulse signal.

Grid converter (three-phase VSR) in two-phase synchronous rotating coordinate system (d, q) under the current equation is:

$$\begin{cases} u_d = e_d + \omega L i_d - R i_d - L \dfrac{d i_d}{dt} \\ u_q = e_q - \omega L i_d - R i_d - L \dfrac{d i_q}{dt} \end{cases} \tag{1}$$

Grid inverter SVPWM control technology is based on the converter to control the space voltage vector switching converter of a new control method, which once came to widespread attention, has become a hot topic.

We can see that the analysis of three-phase voltage-type PWM rectifier AC side voltage different switch combinations can use a space voltage vector in the two-phase stationary coordinate system (α , β) under representation. Eight kinds of switching states corresponding to the eight basic voltage vectors, wherein the vector is a modulo six non-zero voltage vector $2U_{dc} / 3$, two vectors are zero vectors.

High-power energy storage converter control contains grid converter control and DC / DC converter control link. Grid inverter SVPWM control technology has been relatively mature ,here we don't make detailed introduction. This paper mainly introduces the droop control strategy for DC / DC converter technology .

DC / DC converter can keep a constant charge/discharge current according to the instruciton in the traditional constant current control mode. But the intermediate dc voltage is maintained by the grid converter , the grid converter is unable to establish the intermediate DC voltage when off-grid. That is to say, it cannot be applicated in off-grid state. The charge/discharge current is in a state of uncontrollable in another kind of dc bus voltage control method . Aiming at the problems of the above two methods, this paper has designed the droop control method for bi-directional DC / DC converters .This method can realize the off-grid operation and ensure a relatively controlled charge / discharge current simultaneoulsly.

Droop control principle is based on "the U_{dc-p} " droop curve designed to determine the output power of DC / DC converter. Droop control contains the sagging charging mode and the vertical discharging mode. In the case of the battery voltage knowable, to determine the output power of DC / DC converter is to determine the instruction value of output current.

Droop control strategy is designed by prolapsed curve to get different current instructions based on different. As changes, the current instruction is constantly changing. Finally it achieves a dynamic balance. At this time, the system power is balanced, and U_{dk} stabilized at a certain voltage value within the allowable voltage range. In this paper, the design of the working range of intermediate dc voltage U_{dk} is 720v to 880v. Voltage fluctuation range is relatively narrow. Droop curve slope is bigger. Adjusted performance degrades and stability deteriorates. Thus this paper presents an improved droop characteristic curve. The interval in the charging and discharging is multiplexed. Therefore, the required voltage regulation range greatly reduced. But the U_{dk} and charging / discharging instruction value is no longer a one-to-one relationship. At this point, it needs the higher system to release the initial charging and discharging state.

Sagging discharge mode (A)

When U_{dk} ≤ V1, it discharges according to the current benchmark.

When V1<U_{dk}<V3, it adjusts the discharge current according to the Linear A based on different.

When V3<U_{dk} < V4, the discharge current is zero, and it stops discharging. It is in the standby state.

When U_{dk} ≥V4, it automatically switches to "droop charge mode" and charges according to the reference current.

Sagging charging mode (B)

When U_{dk} ≥ V4, it discharges according to the current benchmark.

WhenV2<U_{dk}<V4, it adjusts the charge current according to the Linear B based on different.

WhenV1<U_{dk}<V2, the charge current is zero, and it stops charging. It is in the standby state.

When U_{dk} ≤V1, it automatically switches to "droop discharge mode" and it discharges according to the reference current.

As can be seen, the voltage range of a discharge state (V3~ V4) and the voltage range of the state of charge (V1~ V2) play a role in the voltage of the dead band. In fact, assuming the battery energy storage system discharging power is P1 and charging power is P2 .and are determined by the control target of superior micro-grid monitoring and dispatching system. Assuming the number of branches can be put into operation is n and the SOC values of the corresponding battery is S_i, I = 1 ~ n. From this, each of branches discharge / charge reference current can be calculated. When calculating value and set value, P1 and P2 needs to have a certain margin compared with the actual. As the following formal:

$$\begin{cases} I_{iA} = \dfrac{P_1}{U_{bati}} \bullet \dfrac{S_1}{\sum\limits_{m=1}^{n} S_m} \\ I_{iB} = \dfrac{P_2}{U_{bati}} \bullet \dfrac{1 - S_i}{\sum\limits_{m-1}^{n} (1 - S_m)} \end{cases} \tag{2}$$

Then, calculate the discharge / charge current reference current of all the branches. Droop control has many advantages in practical applications. On the one hand, it not only can be run in the state grid, can also run in off-grid state. On the other hand, it can reasonably allocates the various branches of power according to SOC of the battery pack to achieve effectively control of input / output power of each branch and relatively control of charge / discharge current .

4 Conclusion

The distributed power in the micro grid has is random, intermittent and not stable, so it needs high power energy storage equipment to serve as its complement. This paper has developed a high-power energy storage converter and achieved bi-directional exchange of energy .We aimed at that batteries serve as energy storage devices in micro-grid system. In this paper, the research and development of power storage converter can realize multiple sets of independent control of the battery, flexible configuration of the system capacity and flexible cutting of the battery pack. Structural design uses mufti-level topology. Control strategy designed to be grid converter adopts SVPWM control technology. DC / DC converter designed to improve the droop control strategy based on environmental design. In this paper, the design of high power converter product has completed droop control charge and discharge and storage full power grid experiment. Charge and discharge current accurate track instruction current grid and the efficiency is more than 95%. This paper has verified the rationality and effectiveness of the design. The product 100 kv bidirectional converter has become a light complementary storage energy storage is an important part of power system. This paper is funded by "2014 Annual colleges and universities excellent talents support program of Liaoning Province".

Acknowledgements. This work is supported by National Nature Science Foundation of China under Grant 61371200 and the Key Project of Chinese Ministry of Education under Grant 212033.

References

1. Atabi, F., Namini, E. M. and Rasooli, A.: Investigating the Feasibility of Applying Integrated Photovoltaic and Solar Water Heating Systems in Residential Buildings [C]. Proceedings of 2012 International Conference on Environment, Energy and Biotechnology, (2012), October 11-16.
2. Research on High Power Buck Converter for Fuel Cell Electrical Vehicles [C]. Proceedings of 2010, the 3rd International Conference on Power Electronics and Intelligent Transportation System (Volume 2), (2010), August 20-25.
3. A. Rathore. Design and Performance Evaluation of a Dual-Bridge Series-Parallel Resonant Converter [C]. Proceedings of 2010 The 3rd International Conference on Power Electronics and Intelligent Transportation System(Volume 4), (2010), October 12-18.
4. Rathore, A.: Modified Complex Ac analysis of a LC-LC Resonant Converter with Secondary Switching [C]. Proceedings of 2010 The 3rd International Conference on Power Electronics and Intelligent Transportation System(Volume 4), (2010), August 21-27.
5. Study on Producing and Rejection Mechanism of Voltage and Current peak Based on Phase-shifted Full Bridge Converter [C]. Proceedings of 2010 The 3rd International Conference on Power Electronics and Intelligent Transportation System(Volume 3), (2010), August 16-21.
6. Design of a digitally-controlled LLC resonant converter [C]. Proceedings of International Conference on Information and Electronics Engineering （ICIEE 2011, (2011), October 20-26.
7. Energy Saving Control Technology of DC-DC Half-Bridge Converter [C]. Proceedings of 2010 International Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE 2010) Volume 4, (2010), October 11-14.
8. Nakajo, A., Kido, H.: A Study of Lighting Circuit for LED Lighting Equivalent TO 60W TYPE INCANDESCENT LAMP [C]. Proceedings of 4th Lighting Conference of China, Japan and Korea, (2011), October 20-25.
9. Ura, R., Makimura, S.: A Study of Step-Dimmable Induction Lamp System [C]. Proceedings of 4th Lighting Conference of China, Japan and Korea, (2011), October 15-19.

