Simulation analysis of DC bus short circuit fault in electrochemical energy storage power station

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Abstract. The paper builds a unified equivalent modelling simulation system for electrochemical cells. In this paper, the short-circuit fault of DC bus in energy storage power station is analyzed and simulated. The short circuit of DC bus is composed of three parts: short circuit current provided by energy storage battery, short circuit current provided by power grid and short circuit current provided by DC energy storage capacitor. The factors that affect the amplitude of three kinds of short-circuit current are summarized to provide reference for reducing the DC short-circuit current of energy storage station.

1. Introduction
In modern power systems, power generation, transmission, distribution, and power consumption must be completed in an instant, and this type of power consumption can be changed after an energy storage power station is added to the power system. Large-capacity energy storage plays a role in peak shaving and valley filling in the power system, and is also a need to solve the contradiction between large-scale use of new energy and grid connection. Battery energy storage power stations are mainly composed of battery packs, inverters, monitoring and management systems, etc. Generally speaking, they are directly connected to the power system via grid-connected transformers. At present, the domestic large-scale battery energy storage system is still in the preliminary research and test stage.

Electrochemical energy storage has been widely used in the field of distributed generation because of its convenient installation and flexible capacity configuration. Electrochemical energy storage mainly refers to various battery energy storage technologies, including lead-acid battery, mobile battery, lithium battery, sodium sulfur battery, etc. With the increasing capacity of electrochemical energy storage, its influence on power system is more and more obvious. It has become an urgent problem in the field of power system simulation to establish an accurate energy storage system equivalent model. According to the different grounding modes of DC system, the paper analyzes the electrical characteristics of DC system pole to pole fault and ground fault respectively, and puts forward corresponding protection strategies, but does not analyze the impact of DC short circuit on the AC side of energy storage station. In reference [2], it is proposed to use the detection functions of converter such as low voltage and over-current for DC system protection, which can not fully reflect the characteristics of DC short circuit. In this paper, the detailed equivalent model of the DC side of the energy storage system is established, and the analysis of the components and influencing factors of the short-circuit current when the DC bus of the energy storage system has a short-circuit fault is emphasized. It can provide model support for the study of the characteristics of the energy storage system and the application of the energy storage system in the power system and other fields, and
provide ideas for the selection of energy storage system equipment and relay protection, and has strong theoretical and practical value.

2. DC bus short circuit modeling of electrochemical energy storage power station

After the large-scale energy storage battery is connected to the power system, it will undoubtedly affect the operation state and performance of the power grid. Multi node large-scale power system simulation research. The equivalent model of energy storage system for large-scale multi node power system simulation is established. The current equivalent model of energy storage system is ur-l equivalent model, which attempts to describe the characteristics of energy storage system with a series of constant voltage sources and resistance inductors. Although it has a good description ability, it can not simulate the output limit of energy storage system and is not suitable for energy storage application simulation [2], but it has a more accurate accuracy for electromechanical transient simulation of power system, especially for short circuit, open circuit and other faults.

![Figure 1. Simulation System of DC Grounding Fault of Energy Storage Power Station](image)

3. Simulation of DC short-circuit process in energy storage power station

Establish a simulation system in PSCAD/EMTDC. The entire energy storage system is connected to the DC bus by the battery pack through the connection cable, and then connected to the converter. After the converter comes out, it is connected to the grid-connected transformer through the three-phase line and finally connected in the distribution network. A polar short-circuit fault occurred in the DC part of the system, and the fault point was located at 50% of the battery cable. Reference power Pref=0.5MW, Qref=0.01MVar. The energy storage power station runs in parallel with the distribution network[3].

\[
I_p(s) = I_p + \frac{U_p}{R} + I_p \frac{1 + \tau s}{\tau s}
\]  

(1)

In the formula, \(I_p\) is the proportional coefficient, \(I_i\) is the integral coefficient, and the time constant \(\tau = k_p / k_i\). \(I_{ss}\) is the steady-state short-circuit current.

The value of the transition resistance \(R_t\) affects the magnitude of the steady-state short-circuit current. When a metallic short-circuit occurs, the steady-state short-circuit current of the battery pack is very large and may exceed the maximum allowable current of the battery. Action to ensure that the battery will not be damaged. When short-circuited by the transition resistance, no matter whether it is low resistance or high resistance, there will be short-circuit current on the ground wire, which can be used as the basis for determining the fault on the side[4].
For the fault current that occurs at t=0.5s, for the midpoint grounded DC system of the battery pack, set the ground fault of the positive connection line at 0.5s, the transition resistance is 0.3Ω, and the current on the positive connection line; In the system, the ground fault of the negative connecting line is set at 0.5s, and the transition resistance is also 0.3Ω.

Table 1. Main model parameters of electrochemical energy storage power station

| element                        | data                  |
|--------------------------------|-----------------------|
| Battery DC Voltage             | 800V                  |
| Battery pack connection cable  | 2x185mm\(^2\)         |
| DC storage capacitor           | inductance \(L_i/\text{H}\) |
| Inverter                       | 0.5MW                 |
| AC Voltage                     | 380V(AC)              |
| Grid-connected transformer     | 1MVA                  |
| Ground resistance              | 0.1                   |
| Transition resistance          | 0.3                   |

When the midpoint grounding method of the battery pack is used, even if there is a transition resistance, the fault current is still very large, so the transition resistance has little effect on the protection, and the protection can still operate correctly; and for the DC system with the battery pack negative grounded, when the negative When a ground fault occurs on the line, due to the influence of the transition resistance, the current at the first end of the negative connecting line flowing into the negative pole of the battery pack is not much different from that before the fault, which may cause the protection to fail and seriously affect the safe operation of the power station\(^5\).
It can be seen from the above figure that when a polar fault occurs on the connection line, the fault can be detected by the large current on the ground line, but when a fault occurs on the connection line, because the current on the ground line is very small, and the current at the first end of the negative connection line is normal, the situation is not much reduced, so although under-quantity protection can be used, the sensitivity is not high [6].

Therefore, we found in the simulation process that the electrical quantity in the system during short-circuit fault has the following characteristics: First, the current flowing at the outlet of the battery pack and the connection between the battery pack connection line and the DC bus increases much more than normal; Due to the discharge, the terminal voltage of the DC energy storage capacitor drops significantly; third, the current flowing through the inverter connection line is greatly affected by the system parameters and does not have obvious fault characteristics. The characteristics of inter-pole faults in DC systems with different grounding methods are the same, so the inter-pole fault protection scheme is applicable to DC systems with various grounding methods.
The following conclusion can be drawn from the simulation diagram: if the DC side uses the midpoint grounding method of the battery pack, the AC side phase current waveform will not be affected, but if the DC side uses the battery pack negative grounding method, then the AC side phase current waveform will increase. This is because there is a DC current component. In this way, under normal circumstances, a large phase current is likely to cause a malfunction of the protection device and affect the normal operation of the power station. The current of the battery pack circuit and the parallel battery pack circuit increases immediately when a fault occurs, which is more than a dozen or even dozens of times under normal conditions. At the instant of fault, the energy storage capacitor starts to discharge, and the loop current quickly reaches its maximum. After that, due to the damping effect, the current almost decay to zero. When the fault occurs, the AC system provides fault current to the system through converter rectification. The loop current is small due to the large impedance of the converter and filter in the loop.

4. Short circuit fault between poles of DC bus and its protection scheme

The electrical quantity in the system during the inter-pole fault has the following characteristics: First, the current flowing through the outlet of the battery pack and the connection between the battery pack connection line and the bus increases much more than normal; second, the energy storage capacitor The terminal voltage drops greatly; third, the current flowing through the inverter connection line is greatly affected by the system parameters and does not have obvious fault characteristics. The characteristics of inter-pole faults in systems with different grounding methods are the same, so the inter-pole fault protection scheme is applicable to systems with various grounding methods.

In order to ensure that the protection cooperates with each other, and there is no refusal or misoperation, the positive current direction needs to be defined, similar to the current direction protection in line protection. The current is specified to be connected by the battery pack, bus and converter side. The cable is in the positive direction, and considering the particularity of the bus protection, it is stipulated that when the current direction of all feeder cables connected to the positive bus is negative, that is, the current flows from the cable into the bus, the bus failure can be determined Open bus protection, otherwise blocking protection is called comprehensive forward blocking protection[7].
When the protection of the lower-level connection cable refuses to move for some reason, after a certain delay, the comprehensive positive lock is opened, and the fault is eliminated by the upper-level protection. In other words, each protection has superior protection as backup protection. For example, when the AC system fails, a frequency-doubled current component will be generated on the system side. Therefore, the protection at the outlet of the positive bus can be used as backup protection for AC system protection. According to the simulation results, it can be known that for the midpoint grounded system of the battery pack, when a polar fault occurs, the installed protection can be correct, effective, and fast action, the same as the theoretical analysis.

5. Conclusion

Based on PSCAD / EMTDC software platform, a large-scale storage battery power station model and its connected distribution network simulation model are established. This paper studies the basic structure of large-scale storage battery power station, establishes the simulation model of the storage battery power station, and analyzes the operation characteristics and fault characteristics of the storage battery power station. Through theoretical analysis and simulation research, the short-circuit current component of DC bus under different grounding modes and its influence on the frequency and voltage of AC side are analyzed. According to the different grounding modes of DC system, the fault characteristics of DC system and the interaction between AC and DC faults are obtained by fault analysis. Based on these changes, the corresponding protection configuration is proposed, and the effectiveness of the protection scheme is verified by simulation.

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