Study on the Fault Characteristics in LVDC System using the Capacitor Midpoint Grounding

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Abstract—Recently, the Low Voltage DC (LVDC) system has been receiving attention since it has many advantages. Also, various studies and developments have been tried because there are many differences from AC systems. Especially, the grounding characteristics of the DC system have huge difference, in terms of sensing, corrosion, etc. So, in this paper, the fault characteristics in LVDC system was studied when capacitor was used as a midpoint grounding for the electrical safety.

Keywords—Capacitor midpoint, Electrical safety, Fault characteristic, Grounding system, LVDC

I. INTRODUCTION

The power system has various configurations such as TT, IT, and TN depending on the configuration of the ground system\textsuperscript{[1]}. In particular, in the case of DC power system which has polarity, it is possible to configure the further more cases and each system has different characteristics according to the grounding system.

The Low Voltage DC (LVDC) system has higher energy efficiency than the AC system and can minimize a power conversion loss due to the spread of renewable energy sources. Thus, LVDC is spotlighted as the next generation energy system. However, since a short period of research and absence of utilization, the verification of the system has not been achieved. Also, since the standardization has not been completed, it makes difficult to commercialize it. Until now, the most related studies have been conducted on energy efficiency, energy conversion, and protection relay algorithms in LVDC system\textsuperscript{[2, 3]}. On the other hand, research conducted in connection with ground, is insufficient. Therefore, this paper is about the form of the LVDC ground using the capacitor for use in the consumer stage\textsuperscript{[4]}. The midpoint ground is constructed using resistors and capacitors to prevent loss in the normal state. Matlab/Simulink was used to verify the fault characteristics of the capacitor midpoint ground, and an experiment was conducted to verify these.

II. GROUNDING SYSTEM IN 2-WIRE DC SYSTEM

A. Classification according to IEC60364

The power system is classified according to earthing at source and earthing in the distribution(exposed-conductive-parts) in the IEC 60364. The representative systems are TT, IT, TN-C, TN-S and TN-C-S. The AC system which have the neutral point can be classified easily based on above, but the 2-wire DC system(mono-polar system), which do not have neutral point, are not. So, there are some paper that the high resistances were used to make the artificial neutral point. However, this grounding system flows the current through the resistances and generates the loss(heat) in normal state. Consequently, the biggest advantage of the LVDC system, efficiency, gets worse. To solve the problem, diode, thyristor and so on have been proposed in the papers.

B. Midpoint grounding using the Capacitor-resistance serial connection

When using the midpoint grounding system in 2-wire DC system, in this paper, the capacitor, which is considered as OPEN state in steady DC circuit, was used to block the current and reduce the loss in normal state. The resistance and capacitor are in serial and artificial neutral point was grounded on earth like in fig.1. By using the resistance with capacitor in serial, it can reduce the capacitor discharging current when fault occurred. The peak current of the capacitor discharge can be obtained in IEC 61660-1\textsuperscript{[5]}.

\begin{equation}
    i_{pc} = k_c \frac{E_c}{R_{CBR}}
\end{equation}

Here, \( k_c \), \( E_c \) and \( R_{CBR} \) were the coefficient, capacitor voltage before the fault and equivalent resistance, respectively. To confirm the fault characteristics of capacitor midpoint grounding system, Matlab/Simulink was conducted.

III. SIMULATION AND RESULT

A. Simulation circuit

Fig.1 shows the simplified simulation circuit consisted of DC power source(Vs), load, midpoint grounding(R1, C1) and fault simulator(Rf). Specific parameter were in table1. The fault between positive pole and PE line occurred at 0.03 [s]. The 6 cases simulations were conducted according to midpoint grounding conditions.

![Simulation Circuit Diagram](image)

**Fig. 1 Configuration of Matlab/Simulink Simulation**

<table>
<thead>
<tr>
<th>Table Head</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vs</td>
<td>380</td>
<td>[V]</td>
</tr>
<tr>
<td>Rf</td>
<td>10</td>
<td>[Ω]</td>
</tr>
<tr>
<td>Load</td>
<td>380</td>
<td>[Ω]</td>
</tr>
<tr>
<td>Midpoint Grounding</td>
<td>R1</td>
<td>100, 1000</td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>0(short), 3, 30</td>
</tr>
</tbody>
</table>
B. Simulation result

Fig. 2 shows the fault current through the PE line when R1 was 100 [Ω] in midpoint grounding. The peak current was 3.11 [A] and it had 1.44 [A] value at the time constant in the cases using the capacitor. In case using the resistance only, there was no decaying and fixed fault current was flowed. In cases using capacitor, the time constant were 0.29 [ms] and 2.78 [ms].

According to the IEC 60479-2, the time constant (T) is time required or the amplitude of an exponentially decaying quantity to decrease to 0.3679 (=1/e) times an initial amplitude and the shock-duration of a capacitor discharge is equal to 3T[6, 7]. Based on the time constant, the minimum protective equipment operating time can be researched in the future works.

Fig. 3 shows the fault current through the PE line when R1 was 1000 [Ω] in midpoint grounding. The peak current was 0.372 [A] and it had 0.137 [A] value at the time constant in the cases using the capacitor. In case using the resistance only, there was no decaying and fixed fault current was flowed. In cases using capacitor, the time constant were 3.0 [ms] and 30.49 [ms].

The simulation time constant of all the cases similar to time constant of the RC circuit discharge. Also, in accordance with capacitance increase, time constant increased.

With increasing the resistance, the peak current was reduced but there was not a 10 times difference due to the voltage distribution with fault resistance and load. The voltage of the fault point was shown in fig. 4. With the change of resistance from 100 [Ω] to 1000 [Ω] in the midpoint ground, the peak voltage of the fault point were decreased for 31.15 [V] to 3.72 [V].

As using the capacitor and resistance, the fault current was disappeared slowly. So, the protective equipment should be detect the fault shortly and the discharge current need to be maintained for the detection.

IV. Conclusion

In this paper, the LVDC system using the capacitor midpoint ground was described when a fault occurred. The loss in normal state when resistance were used only as a midpoint can be reduced by using the capacitors. Also, the proposed configuration, serial connection between resistance and capacitor, has characteristics similar to RC discharging current, like time constant. Based on this paper, the electric shock and the fault analysis considering the line capacitor will be studied.

REFERENCES