POWER QUALITY IMPROVEMENT BY CONTROLLING FAULT CURRENTS USING NSFCL

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Abstract : The most common ways to limit fault currents are cost effective and less flexible. This paper proposes a new structure which improves power quality by controlling magnitudes of fault currents using NSFCL in all fault conditions automatically. To control the magnitude of fault current, a discharging resistor is used in this structure. In addition a logical circuit is implemented to make the circuit as automatic operated. By logic circuit, it is possible to reduce the magnitude of fault current to a very low desired value by comparing dc reactor current with constant value of current. The proposed NSFCL was simulated with the help of MATLAB (Simulink).

IndexTerms - Fault current limiters (FCLs), Fault currents, Nonsuperconducting coils, Thyristor controlled rectifier, AND Gated logic circuit.

1. INTRODUCTION

As the utilization of power becomes more, the Power quality problems are also increases. One of the major causes for this reduction of power quality is short circuits. Whenever short circuit occurs, the large amount of current flows through the power system network. Hence the magnitude of fault current will increase and it damages the load and as well as the system.

To protect the system from these high currents switchgears are used. While operating these switchgears in the fault conditions, interruption will occurs in the continuity power supply. To overcome this major disadvantage or to avoid the interruption in the supply, Fault Current Limiters are used.

An ideal FCL should have zero resistance at normal operation, less power loss, gives large impedance in fault conditions, quick recovery after fault removal, reliable current limitation, reliable and economical.

Different configurations of FCLs are Is-limiters, solid state fault current limiters (SSFCLs) and superconducting fault current limiters (SFCLs). Due to natural low losses in superconductors, this SFCL control the fault currents in normal conditions. Unfortunately, because of high technology and cost of superconductors, these devices are not commercially available. Therefore, replacing the superconducting coil with nonsuperconducting coil in FCL makes it simpler and much cheaper. It should be noted that the main drawback of nonsuperconductor fault current limiter (NSFCL) is power losses that is negligible in comparison with the total power, provided by the distribution feeder.

This paper proposes a controllable simple structure and cost effective NSFCL to restrain the magnitude of fault current to a certain desired value. In addition, the proposed structure is capable enough to reduce the fault currents in NSFCL. To make the entire circuit as flexible and reliable, a logical circuit which makes a semiconductor switch operates automatically under the fault condition is also implemented and proposed in this structure. The circuit operation in normal and fault conditions are simulated and experienced. The experimental results are in good agreement with simulation of circuit operation both of which are carried out in distribution voltage levels.

2. POWER CIRCUIT TOPOLOGY

A three-phase transformer, used as voltage transformer, is connected to a three-phase diode bridge rectifier. The three-phase diode-bridge rectifier takes the supply from the voltage transformer and connected in parallel with the discharging resistor and semiconductor switch which is controlled by control circuit. This rectifier is also called as voltage transformer rectifier. Three sets of single-phase linear transformers combined structure is used as the isolation transformer and connected to a three-phase rectifier. And a non superconductor (copper coil) magnet and a DC reactor are connected in series with this rectifier. And DC reactor is connect to the other side of parallel connection of a discharging resistor and a semiconductor switch as shown in figure.
2. OPERATION PRINCIPLES

In normal operation i.e., without fault condition semi-conductor switch is closed means the switch is turned ON by the control circuit. And resultant current flows through the diode rectifier and short circuit path of semiconductor switch. And normal current flows to the thyristor circuit. Increased inductance value decreases the ripple of D.C current and that power is compensated by the transformers.

During the fault condition, that means when fault takes place at load side then load will act as the source and high currents flows from load to source. Then high currents flows through rectifier. It convert that high ac currents into high dc currents and flows through DC reactor and then flows through the discharging resistor. When semiconductor switch opened that means turn OFF by control circuit. Then that high dc currents decreased by flows through the discharging resistor. Hence the decreased currents flows through the voltage transformer which is act as inverter in fault condition.

In this paper, a control circuit is proposed as mentioned above. By the control circuit the ON and OFF of the semiconductor switch is automatically done. In normal cases, the current flowing in DC reactor is compared with constant current value of magnitude of normal current in control circuit. But in fault conditions, magnitude of fault currents are more compared to normal current levels. Then AND gate input signal is low and another one is always high so the AND gate is not activated, no gate signal for thyristor switch. Finally semiconductor switch is opened. Hence high currents flows through the discharging resistor and the magnitude of fault currents reduced to desired value. In normal case, both the inputs of AND gate are logically high. So that the pulse signal makes the thyristor ON. Hence normal currents flows through the short circuited path of semiconductor switch.

By this additional structure i.e., by the control circuit of NSFCL, magnitude of fault currents are controlled to desired value. Hence power quality gets improved.
The compensating voltage provided by rectifier is \( V_c = 2V_{DF} + V_{SW} + r_d I_d \)

Where

\( V_c \) is compensating voltage provided by the voltage transformer rectifier
\( V_{DF} \) is forward voltage drop across rectifier diodes
\( V_{SW} \) is voltage drop across semiconductor switch
\( r_d \) is resistor of copper coil
\( I_d \) is current flowing through the copper coil

### 3. SIMULATION RESULTS

The power circuit topology, shown in Fig. 1, is used in simulation. The simulation parameters (Table 1) are also used in laboratory prototype.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Content</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_S )</td>
<td>Source voltage</td>
<td>380V</td>
</tr>
<tr>
<td>( r_S )</td>
<td>Source resistance</td>
<td>1Ω</td>
</tr>
<tr>
<td>( r_d )</td>
<td>DC reactor resistance</td>
<td>0.2Ω</td>
</tr>
<tr>
<td>( L_d )</td>
<td>DC reactor inductance</td>
<td>0.2H</td>
</tr>
<tr>
<td>( r_P )</td>
<td>Discharging resistance</td>
<td>51Ω</td>
</tr>
<tr>
<td>( r_{Load} )</td>
<td>Load resistance</td>
<td>30Ω</td>
</tr>
<tr>
<td>( L_{Load} )</td>
<td>Load inductance</td>
<td>100H</td>
</tr>
</tbody>
</table>

Table-1

The simulation results are obtained NSFCL operation performance of a thyristor circuit at a fault condition, where a three phase to ground fault occurs at load side. The neutral of source grounded. The various operation performances are carried out as follows. The below, figure.2 and figure.3 shows the magnitudes of respective Voltages and Currents at normal condition. Figure.4 shows the line current just after fault without using semiconductor switch. Figure.5 is the result of magnitude of reduced fault current after semiconductor switch opened. Voltage drop during fault is shown in figure 6. And after semiconductor switch opened, the voltage level is improved which shows in figure 7. DC reactor current at normal condition is shown at Figure 8. And DC reactor current just after fault without using the semiconductor switch is shown in the figure.9. When the semiconductor switch turned ON, the magnitude line fault currents are reduced and the DC reactor currents also minimized for low desired value as shown in Figure 10.
Figure – 2

MANITUDE OF VOLTAGE AT NORMAL CONDITION

Figure – 3

MAGNITUDE OF CURRENT AT NORMAL CONDITION

Figure – 4

MAGNITUDE OF FAULT CURRENT WITHOUT SEMICONDUCTOR SWITCH OPENED.

Figure – 5

REDUCED FAULT CURRENT MAGNITUDE BY OPENING SEMICONDUCTOR SWITCH
Figure 6

VOLTAGE DROP DURING FAULT (BEFORE OPENING SWITCH)

Figure 7

INCREASED VOLTAGE DROP (AFTER OPENING SWITCH)

Figure 8

DC REACTOR CURRENT AT NORMAL CONDITION
4. CONCLUSION

In power systems, the three phase to ground fault is rarely occurred severe fault. Whenever this fault occurs, abnormal currents flows through the system. These high currents are the major cause of reduction in power quality. To improve the quality of power or to reduce the high currents, a modified NSFCL is proposed with the addition of control circuit. The major advantages of this new structure are continuity in the supply, protects the load from the fault currents. Hence, the power quality is improved in the power system. And the added inductance in the circuit causes power loss in the circuit, that power loss is compensated by the voltage transformer. As compared to SFCLs, the power loss is considerable disadvantage in NSFCL. But this structure is more advantageous in construction, cost and reliability comparisons. And an additional control circuit helps to operate the entire system flexible and more reliable. By considering these above features, it is possible to increase the scope of FCLs in future.

The simulation results demonstrates the ability of the proposed circuit to limit the fault current to any desired value.
6. REFERENCES


