SHORT CIRCUIT CURRENT LIMITER IN AC NETWORK

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Abstract: Short circuit is a serious fault in power network. Some novel circuit topologies of current limiter using power electronic technology have been developed, which can limit the fault current to any desired level without much penalty. The operating principle and control strategies of such current limiters are discussed in detail. Simulation and experimental results are given to verify the performance of the current limiter, which can meet the requirements set for locations of bus tie, feeder, as well as the main transformer in the distribution network.

Key words: short circuit protection, current limiter, solid state switchgear, solid state current limiter

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INTRODUCTION

Short circuit in power systems is a serious fault, which may damage the equipment in the system. It requires the protection system to switch off the very high level of fault current. The traditional method to limit the short circuit current level is to serially connect a limiting reactor in the system. However, the consideration of voltage drop and power dissipation of the reactor in normal operation limits the effect of the reactor. Some new approaches for short circuit limiting had been proposed. The EPRI (Electrical Power Research Institute) in the USA carried out a series of investigations into the technologies, which may possibly be used as short circuit limiter. The results of the investigation (Slade et al., 1992; Smith et al., 1993) proposed that a limiter consisting of solid state device such as GTO (in Fig. 1) may be the best approach among other possible approaches. The reactor in Fig. 1 is bypassed by the GTOs in normal operation. If short circuit occurs the GTOs should be switched off very quickly before the short circuit current rises to a high level. It requires fast response of the protection system. When the GTOs are switched off, the reactor L is inserted into the fault circuit. The interrupted current in GTO will transfer to the reactor L with very large $\frac{di}{dt}$. A high frequency resonance will be excited which causes large over-voltage with very rapid $\frac{dv}{dt}$ applied to the GTOs as well as other equipment in the system. To reduce the negative effect, the value of reactor used has to be limited. A traditional breaker S is also needed to finally switch off the limited short circuit current.

Another current limiting approach, the so called lossless resistor (LLR) was proposed (Chen et al., 1994; Chen et al., 1997), which uses IGBTs to form a bridge circuit and PWM technique in power electronics (Fig. 2). According to the authors, if the bridge is operating as rectifier and inverter alternately with modulating frequency higher than the mains frequency, the equivalent resistance of LLR can be controlled. The higher the modulating frequency is, the higher is the value of LLR. With much higher modulating frequency at short circuit, the equivalent value of LLR could be large enough to limit the short circuit current to a desired level.

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With such a topology, the modulated current in the positive half cycle is the same as that in the negative half cycle. The simple topology could not operate properly. Furthermore the switch devices in the bridge are operating in hard switching condition with relatively high modulating frequency and the switching loss is considerable even in normal condition. Abundant harmonics also exist with the approach.

In engineering practice, the current source \( i_c \) in Fig. 3 can be replaced by a reactor \( L \). In this case the reactor, as well as the load, will be charged to its steady state through initial transients. In short circuit the current is limited by the reactor to rise slowly, which allows the protection system to respond easily and switch off the relatively low short circuit current. The reactor current will pass through the paralleled diode (as a freewheeling diode) after switching off without any transient overvoltage until the energy stored in the reactor is exhausted.

CURRENT LIMITER IN DC CIRCUIT

Fig. 3 shows the principle of the proposed current limiter. If the current of the current source \( i_c \) in normal condition keeps larger than the value of load current \( i \), the diode \( D \) will always be at on state. Compared with the high voltage of the voltage source, the very low on state voltage drop of \( D \) will not affect the load voltage. In the case of short circuit, the source voltage acts on the diode \( D \) reversely and turns it off. The fault current rises instantaneously to and is limited by the current of the current source \( i_c \). Once the value of \( i_c \) is set, the peak value of the short circuit current will be limited automatically to the value of \( i_c \), which is easily switched off by the switch \( S \).

CURRENT LIMITER IN AC CIRCUIT

The idea of DC current limiter can be extended to AC network as shown in Fig. 4 (Wu, 1996; Wu et al., 1999). In Fig. 4 b) with \( L_1 \), \( L_2 \) to replace the current source in Fig. 4 a), the currents of \( L_1 \) and \( L_2 \) will reach the peak value of the sinusoidal load current after the initial stage transients have receded. If the power loss of the reactor and diode is negligible compared to the energy stored in the reactor, the current of each reactor keeps constant and the current in each diode always flows except during the peak of the load current (Fig. 4c). Therefore the load current is theoretically sinusoidal and without distortion. If a short circuit fault occurs at any instant in a