

# 3상 변압기의 권수비에 따른 초전도 한류기의 전력특성

## Electric Power Characteristics of a SFCL based on Turn-ratio of 3-Phase Transformer

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(In-Sung Jeong · Hyo-Sang Choi · Byung-Ik Jung)

**Abstract** - At present, the demand for electric power increases, the electric power system is complicated. The size of the line-to-ground fault and the line-to-line fault occurred with complication of electric power system continue to increase, therefore several issues are raised. To address these issues effectively, the superconducting fault current limiter (SFCL) has been proposed, this study is ongoing. In this paper, we applied the SFCL in three-phase transformer and comparative analysis of the electric power burden to the SFCL. The superconductor is combined to the third winding of transformers in connection structure. In case of a third line-to-line fault, we did comparative analysis of the electric power burden to the SFCL based on the turn ratio of transformer third winding. In this case, we could confirm as the third turn ratio increased, electric power impressed to the superconducting element increased.

**Key Words** : Electric power characteristic, Line-to-line, SCR, SFCL, Superconductor, Turn-ratio

### 1. 서 론

Currently, in case of line-to-ground fault and line-to-line fault arising from the electric power grid due to the increased electric power demands, the fault current size continues to increase and exceeds breaking capacity of a circuit breaker. These fault current cause disconnection and breakdown of electric power equipment and protective devices, a massive electric power outage caused by fire, casualties and property damage. To solve these problems, we implement the bus separation and install the series reactor, but problems such as the electric power system's stability, reliability, and electric power quality deterioration, etc. are encountered. To address these issues effectively, the SFCL has been proposed and this study is ongoing [1-2].

Currently, in domestic electric power system if we apply the new circuit breaker, we should suffer economic loss due to the replacement of existing appliance. But the overall principles and structures of the SFCL is simple and the SFCL can be applied without replacing of an existing appliance, there are several benefits to occur. As a result, transformer combined with the SFCL for practical use was devised. Usually superconductor is in 0 resistance status and no loss, but if fault occurs,

superconductor characteristic is lost. This is referred as "quench phenomenon", then impedance is occurred and fault current is limited effectively. And, if fault current flows, superconducting element is quenched, within 1/4 cycle fault current is limited. It minimizes the influence to the external equipment in electric power system and minimizes the damage, as well as after completing the fault current limitation role, within 0.5 sec it is reversed to superconducting status [3-7].

In this paper, electric power characteristics of the SFCL applied to the three-phase transformer was analyzed through the imitating experiment. We did comparative analysis about characteristics of electric power which flows in the SFCL according to third turn ratio of three-phase transformer in case of a triple line-to-line fault. If capacity of the SFCL increase, we can get reliability, so we want to analyze the electric power which occurs in the SFCL and verify the results through this experiment.

### 2. 본 론

#### 2.1 Operation Characteristics of a SFCL

Fig. 1 is the experiment circuit diagram which combined the SFCL on three-phase transformer. Three-phase transformer was on Y-connection. SW-R1, S1, T1 were power switches. In the case of normal operation, the SFCL operated as transformer with circuit, provided the electric power to load, at that time the

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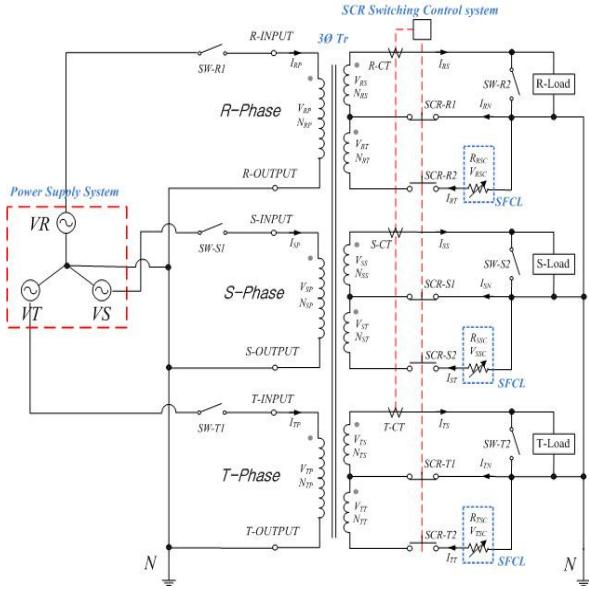


Fig. 1 Three-phase transformer combined with the SFCL

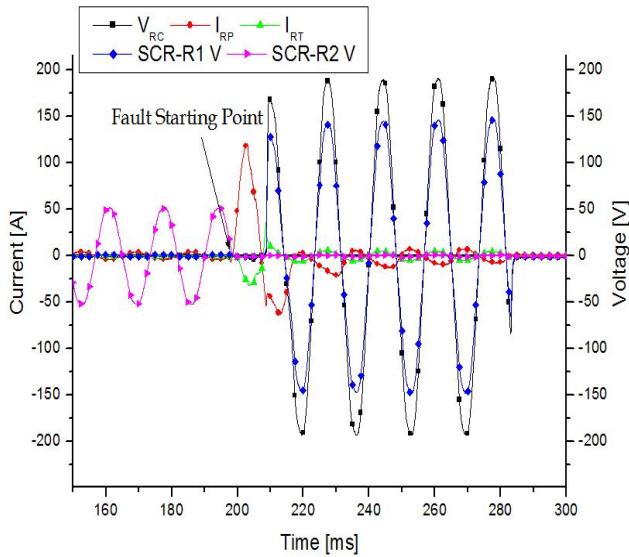


Fig. 2 Current limit curves of the SFCL

SFCL was opened to the line, so no loss occurred.

The fault current occurred, the CT of phase R, S, T detected the fault current, and the switch SW-R2, SW-S2, SW-T2 of each phase started to operate. As a result, the fault current was flowing into the SFCL.

As current over critical current flowed, the SFCL was in quench. Impedance occurred in the quenched SFCL, rapidly increasing impedance limited the fault current.

## 2.2 Current Limit Curves

Fig. 2 shows that in case of a triple line-to-line fault, the fault current size on phase R is limited by the SFCL. At this point, the size of the impressed voltage was 200

V. As you can see in Fig. 1, normal current flowed. SCR-R1 is as “contact b” in on status, while normal current flows voltage do not occurs, SCR-R2 is as “contact a” in off status at ordinary times, the voltage occurs. If the fault occurs, SCR-R1 off, and the SCR-R2 on, as a result fault current flows to the SFCL.

Thence the voltage of SCR-R1 occurred the voltage of SCR-R2 did not occur. SCR-R2 was on, fault current flowed to the SFCL. SCR-R2 became on status, the fault current flowed in the SFCL. If the fault current flows into the SFCL, the SFCL was in quench and made resistive element. As you can see in Fig. 2, resistance caused by the SFCL quench limited the fault current within half-period

### 3.1 Power of the SFCL according to turn-ratio of transformer

#### 3.1.1 Turn Ratio (NP:NS:NT=3:3:1)

Fig. 3 shows electric power which was loaded to the SFCL of each phase if fault occurred according to voltage change which R, respectively, 200, 240, 280 V was impressed, a triple line-to-line fault occurred. When the first fault occurred, electric power burden on the SFCL was 588, 663, 683 W, respectively. Within half-period, the SFCL was quenched, resistance occurred, fault currents were limited as 297, 416, 489 W, the SFCL was increased according to the voltage which was respectively. We could confirm that electric power burden to impressed.

Also, we could confirm that power burden to the SFCL was increased according to the voltage which was impressed on the phase R, S and T

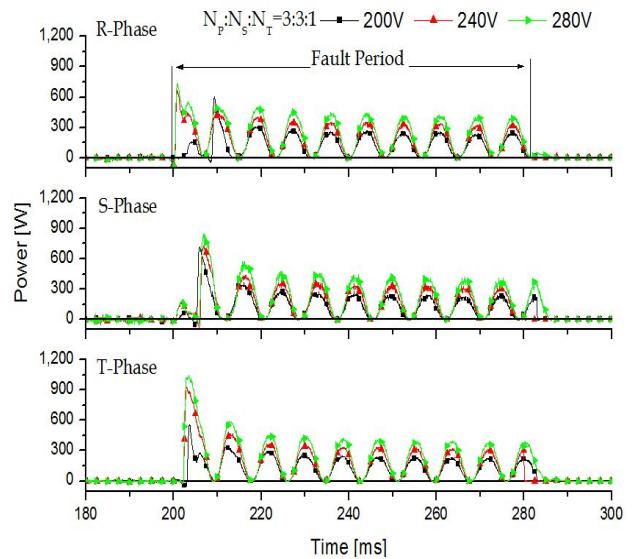


Fig. 3 Power curves of a SFCL according to the transformer turn ratio (NP:NS:NT = 3:3:1)

### 3.1.2 Turn Ratio (NP:NS:NT=3:3:2)

Fig. 4 shows electric power burden to the SFCL was increased according to the voltage which was impressed.

in case of turn-ratio of third winding was 3:3:2. Similarly as 3:3:1 case, 200, 240, 280 V were impressed on each phase respectively, and a triple line-to-line fault occurred. When we checked electric power burden to the SFCL according to the voltage on phase R, while impressed voltage was 200, 240, 280 V respectively, electric power burden to the SFCL was 1,099, 1,332, 2,082 W respectively. After fault occurred, the SFCL was quenched and limited fault current, fault current value were 712, 1,035, 1,354 W respectively.

Similarly as phase S, T, and R, electric power burden to the SFCL was big when fault occurred, after half-period the SFCL limited fault current. In addition, we could confirm that electric power burden to the SFCL was increased according to the voltage which was impressed.

### 3.1.3 Turn Ratio-(NP:NS:NT=3:3:3)

Fig. 5 shows electric power burden to the SFCL according to the voltage which was impressed in case of turn-ratio of third winding 3:3:3. As in Fig. 3, Fig. 5 shows that electric power burden to the SFCL was increased according to the voltage which was impressed. Voltage, respectively, 200, 240, 280 V was impressed, electric power burden to the SFCL on phase R was respectively, 1,654, 1,660, 2,042 W. After fault half-period, superconductor was quenched, the fault current was limited, electric power burden to the SFCL was 963, 1,296, 1,583 W respectively, power burden to the

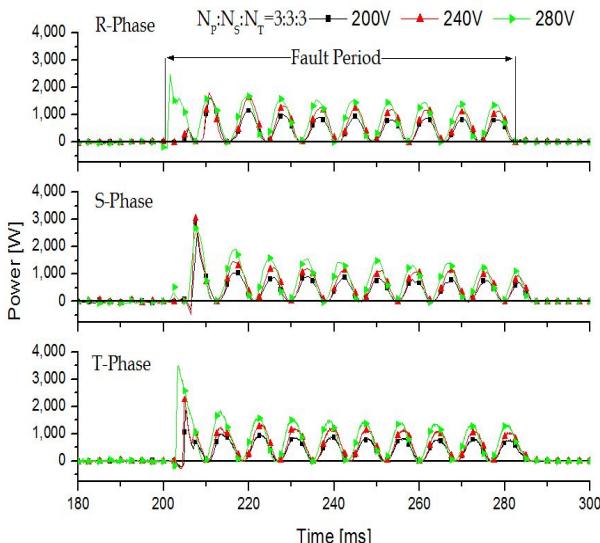


Fig. 5 Power curves of a SFCL according to the transformer turn ratio (NP:NS:NT = 3:3:3)

SFCL was also increased as much as turn-ratio was increased.

## 4.1 Results

Tables (a), (b), and (c) shows electric power change of the SFCL according to third turn-ratio variation.

When we compared electric power burden to the SFCL according to turn-ratio on phase R, S, and T, electric power on phase S and T was relatively large. Also we could confirm through turn-ratio that electric power burden to the SFCL on phase S and T was larger than electric power burden to the SFCL on phase R.

Also, we could confirm that in case of 3:3:1 electric power burden to the SFCL on phase T was bigger than the SFCL on phase R and S, in case of 3:3:2 and 3:3:3 power burden to the SFCL on phase S was bigger than

**Table 1** Change of SFCL Power according to Turn-Ratio NP:NS:NT= (a) 3:3:1, (b) 3:3:2, (c) 3:3:3

Phase	State	200V	240V	280V
R	Fault instant	588	658	712
	After fault			
S	Fault instant	704	704	833
	After fault			
T	Fault instant	537	919	1023
	After fault			

(a)

Phase	State	200V	240V	280V
R	Fault instant	1079	2082	1296
	After fault			
S	Fault instant	1512	1332	2689
	After fault			
T	Fault instant	1185	1099	2180
	After fault			

(b)

Phase	State	200V	240V	280V
R	Fault instant	1591	1745	2042
	After fault			
S	Fault instant	2851	3078	2657
	After fault			
T	Fault instant	1763	2245	3472
	After fault			

(c)

on phase R and T. This means that even though same fault current flows, power burden on each phase was different, so it seems to prepare some measures for this.

### 3. 결 론

In this paper, we analyzed electric power burden to the SFCL according to third turn-ratio of three-phase transformer combined with the SFCL.

We mocked a triple line-to-line fault in which fault frequency was low, but damage was biggest in case of fault. We could confirm that size of voltage impressed and third turn-ratio increased the more power burden to the SFCL also increased. Due to the increased value of power burden to the SFCL according to the value of electric power, and the increased recovery time according to heating via increasing of capacity with series and parallel connection and increasing of electric power value, so seems to need continuous study.

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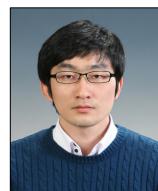
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