

Innovative Idea towards Mitigation of Fault Current by Using Superconducting FCLs

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Abstract- A continuously growing attention has been paid over the years by the international community to monitoring the effects of the increase of fault current on the quality of power. Due to happening of fault, enormous amount of current rush through overall components of the network. Which will imbalances the quality of supply furthermore may cause physical damage to the equipment. This paper deals with the aim to reduce the fault current magnitude by the help of SCFCL (Superconducting fault current limiter). The SCFCL is more advantageous over traditional circuit breakers in limiting fault flows & as well progresses the system's aggregate reliability. A resistive type SCFCL model was designed and developed in SIMULINK/SIMPOWER/MATLAB tool. The several types of failures were analysed at distribution side of the plant and Performance of SCFCL was superior under various fault conditions.

Keywords- SCFCL, Fault current limitation, YBCO, CB, Wind plant

I. INTRODUCTION

The requirement of electrical power was rising due to globalization. In order to generate required amount of power never-ending sources are being added to the typical or conventional power plant. This expansion leads to increase in the pressure over the existing system. Because of all these consequences total impedance of the plant becomes variable. And level of fault currents are become large or vary accordingly.

At the point when there is incidence of faults since naturally occurring failures such as electrical discharge, breakdown of insulation, transmission line hazards, storm adversity or humanoid ruin and so forth, which bring about massive measure of defective current to flow over all the portions of the power scheme [1]. These failures give rise to equipment failure which may leads to interruption of power and individual damage. To counteract the above said dangerous effects of failures, protection of the power system network is taken into account.

Conventional circuit breakers, worked by relays are utilized for protecting HV electrical network. During some fault conditions, current circuit breakers are unable to prevent huge fault currents. Also, typical CB takes a few cycles for initiation [5]. Smart grid is the modern and redesigned electric network, distributed into small systems known as micro grid or small scale network. Micro grid utilizes improved communication abilities and limitless energy resources for upcoming power system. Micro-grid has many benefits over typical network, for example, enhanced power quality, security, safety, and lowered response duration [4]. Undesirably on event of short circuit results in huge current to surge over network & damage the components of grid.

There is a best answer for the above said problems to bring down the level of short circuit current to some extent. This is accomplished by our recently created protection equipment known as "Superconducting Fault Current Limiter". Despite the fact that it is not possible to remove fault completely in any case, however with the assistance of Superconducting FCL we can decrease the deficiency current peak value there by lessening adverse impacts of faults [6] and [7].

Figure 1 shows the working of SCFCL under normal and faulty conditions. It is found that utilization of SCFCL is meritorious over circuit breaker in view of its performance i.e. SCFCL takes 1st half cycle of deficiency current to lower it. SCFCL extensively decreases defective flow. So it enhances stability of the system & transitory firmness of the power network. Likewise SCFCL is cost-effective & hence investments on high rating circuit breakers are saved.

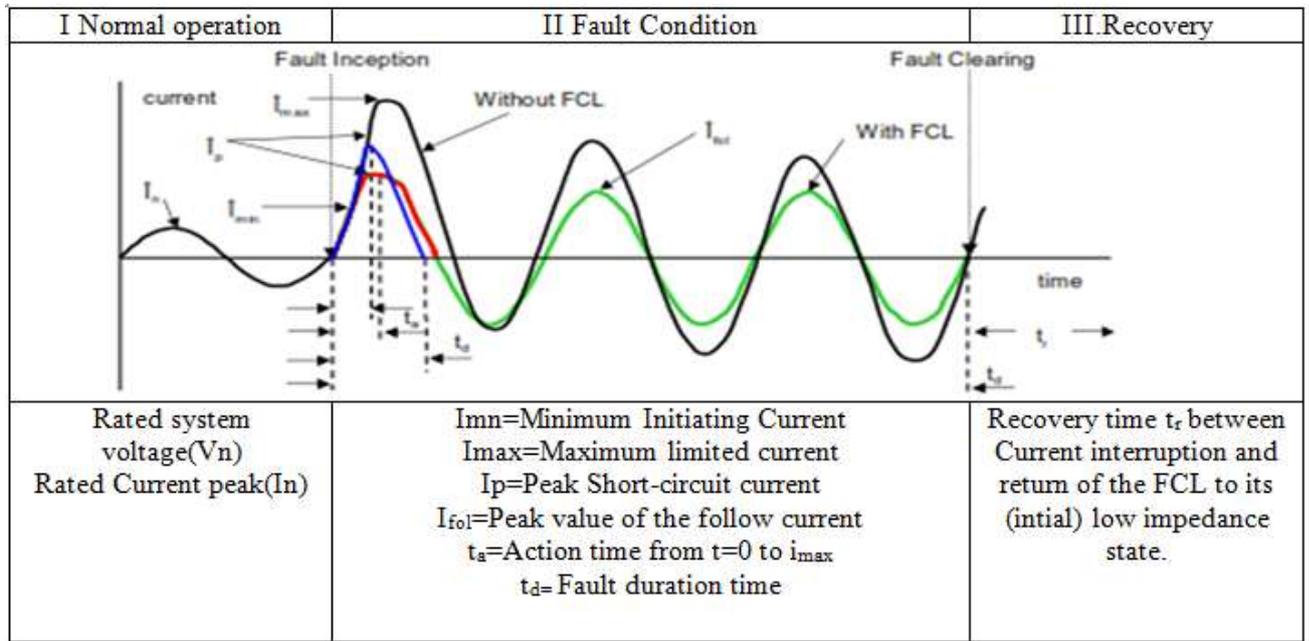


Fig. 1 graph showing function of SCFCL

II. ABOUT SUPERCONDUCTING FAULT CURRENT LIMITER

SCFCL is efficient safeguarding device which is capable to bring down the shortcoming current level in first cycle of the fault current. The reduction of SC current range raises the transitory strength along with complete security of the electric network [2]. This failure current reducing actions of the SCFCL is based on non-linear response to temperature, current & magnetic field deviations. The Conversion from superconducting mode to typical conducting mode/state is due to rise in any of the above mentioned important constraints. Figure 2 shows SCFCL characteristics.

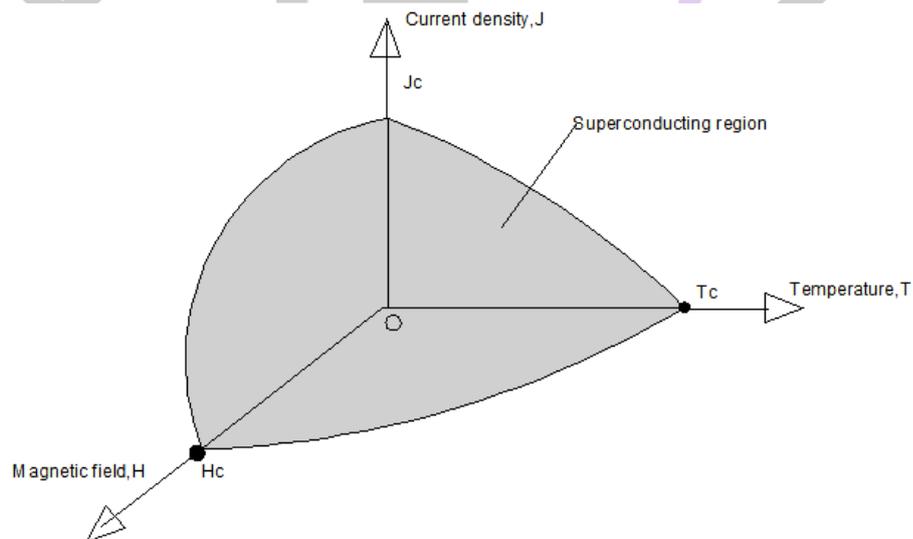


Fig. 2 T-B-J Characteristics of SCFCL

III. MATERIAL DESCRIPTION FOR THE DESIGN OF SCFCL AND ITS FEATURES.

There are two types of superconducting materials which are

1. Higher temperature superconductors (HTS),
2. Lesser temperature superconductors (LTS).

LT Superconductors are the first era superconductors & transition temperature of low temperature superconductors is under 24K.. Because of low working temperature, low temperature superconductor has high cooling rate. For LTS, Liquid helium is used as a cooling material and is around 4.2K. FCLs made up of LTS are costly.

Amid 1986, a most recent, resulting era superconductor was set up. This has generally vast transition temperatures, so the name given High Temperature Superconductors. HTS materials are made of ceramic components. Whose Transformation temperature is around 110 K. HTS are less costly. Fluid nitrogen is normally used to cool the HTS materials working at 77K. Parameter of SCFCLs is given in Table 1.

HTS Based SCFCL construction is reasonable. Normally Magnesium Di boride (MgB₂) & Yttrium –Barium Copper-Oxide (YBCO) are the suitable HTS materials for the construction of SCFCLs. Superconducting FCL design based on HTS material is more beneficial due to its low cost, reduced running costs and thereby low investment expenses [4].

By using SCFCL, it is possible to counter & limitation of SC currents value. There are different categories of SCFCLs and can be grouped in three kinds namely, resistive type, inductive type and bridge kind SCFCL. Table 2 represents model parameters of Superconducting FCL.

There are some features of SCFCL like,

- a. High resistance fault condition
- b. Lesser resistance in usual situation.
- c. Reduces SC current prior to 1st maximum &
- d. handy in advance to circuit breaker recloses, and so on

Table 1 Parameters of the SCFCL

SCFCL Materials	Resistive SCFCL	Inductive SCFCL	Primary coil
YBCO	$J_c=3 \times 10^6 \text{ A/cm}^2$	Thickness=20mm	Copper material No. of turns=184 Core cross section area=0.21m ²
	$T_c=90\text{K}$	Height=2m	
	Sample(A_{sc})=0.4mm ²		
Bi-2212	$J_c=1.5 \times 10^3 \text{ A/cm}^2$	Thickness=20mm	Copper material No. of turns=184 Core cross section area=0.21m ²
	$T_c=87\text{K}$	Height=2m	
	Sample(A_{sc})=0.2mm ²		

IV. DEVELOPMENT OF SUPERCONDUCTING-FCL MODEL

The resistance SCFCL model demonstrated using SIMULINK/MATLAB tool. The design constraints utilized to model SCFCL are given in table below.

Table 2 Design constraints

(i) Transition or response time	2msec
(ii) Maximum impedance	20 ohm
(iii) Minimum impedance	0.01ohm
(iv) Recovery time	10ms
(v) Initiating current	550Ampere

Figure 3 demonstrates the Resistive SCFCL module. In model, Route Mean Square value of the system's line current is discovered by utilizing RMS block [9]. Then it is given to subsystem of SCFCL look up table.

The SCFCL look up table is utilized to inspect level of impedance whether it is high or low. The function of SCFCL is as per the following:

(a) If the supply current is underneath the activating current value, and after that the SCFCL impedance is least

(b) When the supply system current is larger than compared to initiating value. Then its impedance rises to most extreme impedance value.

This causes reduction of fault current.

Figure 4 shows the look up/characteristic table of SCFCL. In which step i/p & transport interval are utilized to adjust the transformation, response & reset time of SCFCL. The switch is utilized for adjusting high/low value of impedance. For removing disturbances filter is employed. The voltage drop is compensated by controlled voltage source.

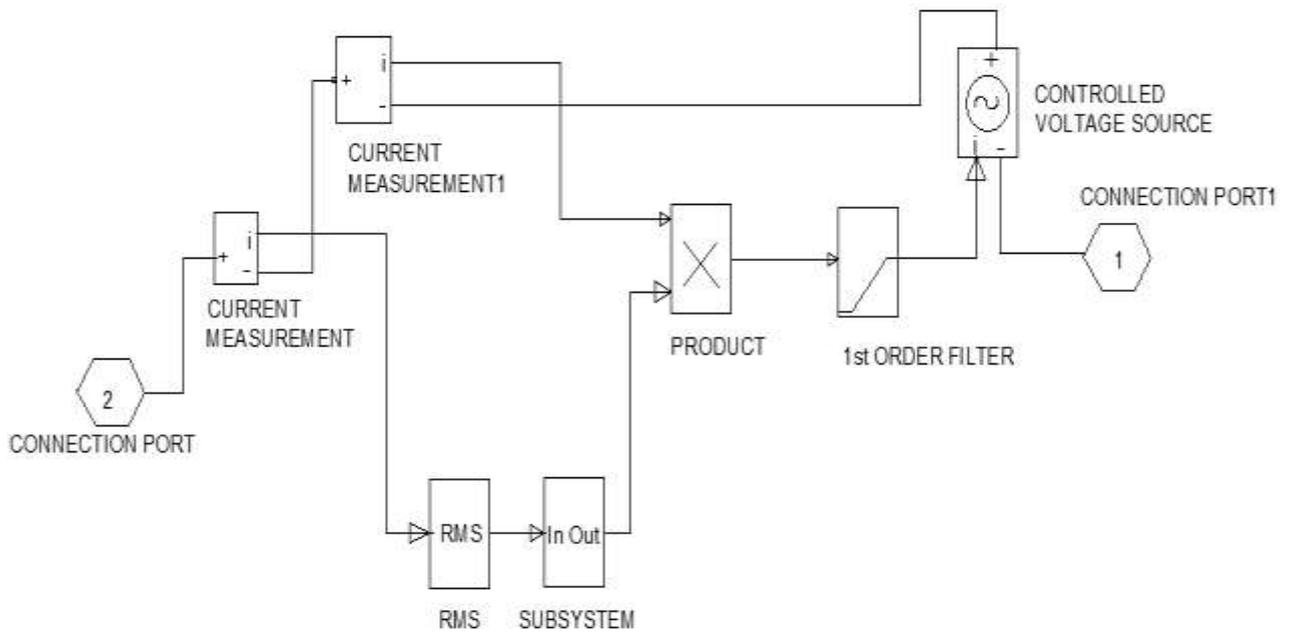


Fig. 3 SCFCL Model

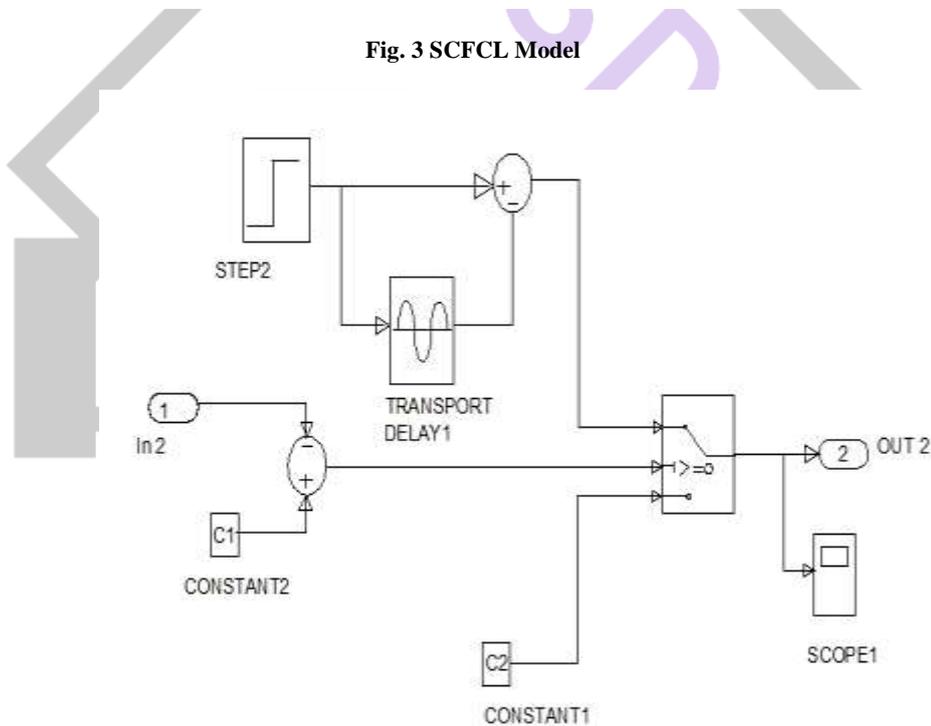


Fig. 4 Characteristic table of SCFCL

Table 3 SCFCL Model parameters summary

Parameter description	Symbol	Value
Superconductor's length(m)	L_{sc}	250
Superconductor's width(mm)	W_{sc}	90
Superconductor's thickness(mm)	T_{sc}	0.12
Ambient temperature	T_a	77
Critical temperature(K)	T_c	95
Superconductor's region exponent at 77K	α	7
Flux flow region exponent	β	4
Critical current density at 77K(A/m ²)	$J_c(77K)$	1.5e7
Electric field at transition from Super conducting mode to flux flow region(V/m)	E_0	0.1
Resistivity of normal conducting state (Ω -m)	ℓ	7e-6
Superconductor's volumetric specific heat(J/Km ³)	C_x	1.5e6
Co-efficient for heat transfer to cooling reservoir(W/Km ³)	K	1.5e3

V. PROPOSED SYSTEM

Figure 5 Shows the developed MATLAB/SIMULINK model of the system under fault condition with SCFCL.

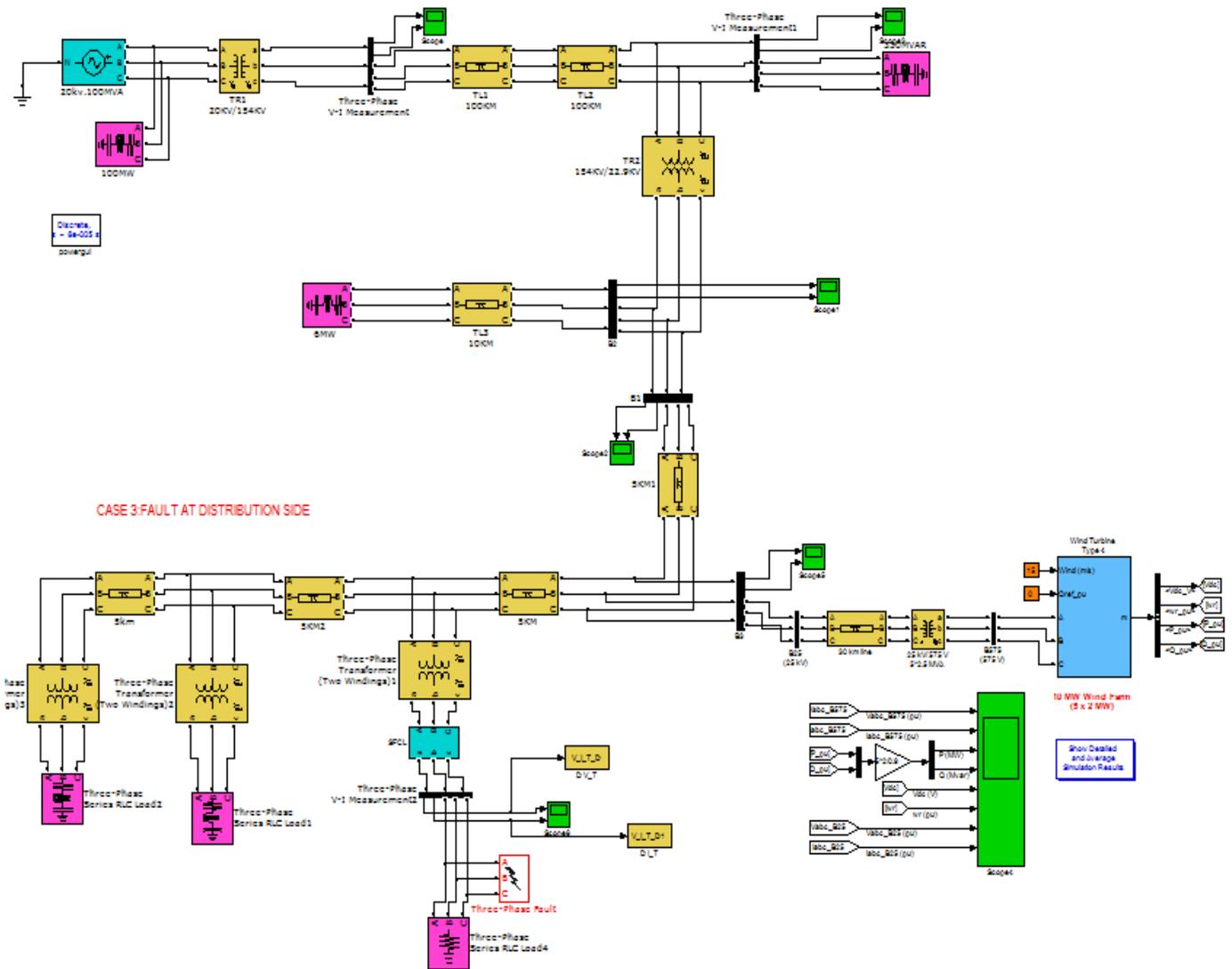


Fig. 5 Simulink module of the system when SCFCL is considered

This section dealt with details of suggested system which is modeled in MATLAB environment. It consists of 3 synchronous machine of 100 MVA, 20KV. This voltage is bring up to 154KV using transformer TR1 of rating 20KV/154Kilo volt connected through 200km transmission line. Using step down transformer TR2, at the sub-station this 154KV is made down to 22.9Kilo volt.

The huge industrial lashes of 6MW & 330 MVA are associated to conventional source. The traditional source is associated by 10 MVA wind plant whose working voltage is 20KV. And through transformer TR3, this voltage is brought up to branch system voltages of 22.9KiloVolt. Through a transformer TR3, the wind cultivate connects with branch n/w B1. By using transformer 22.9KV/400V, the wind-form is supplying residential lashes at 400V. Transmission lines of 5kilo meter were used in between these three loads.

VI. SIMULATION RESULTS

The simulation results are presented for the various faults at distribution side with and without SCFCL.

1. Single Line-to-Ground fault

Under ordinary situation, current and voltage is observed to be 5.4×10^{-2} Amp & 5.4V separately. LG flaw is made at distribution side, and afterward this typical condition has been changed as appeared in Fig. 6 a) In current waveform at LG fault, Current of each phases is zero up to 0.0168second. After 0.0168second, current of the affected phase "a" raised to 1995A which is around 5.4×10^{-2} A under ordinary situation. The other two phase currents are zero. All the phase streams are zero after 0.0886second.

Imbalance framed by disturbance is decreased by SCFCL see Fig. 6 b).we can say it evidently that before introducing SCFCL, current value of defected phase is around 1995A.This massive measure of shortcoming current is lessened with the establishment of SCFCL. After installing SCFCL current is diminished to 425A.It is to be noted here that 0.1sec simulation span is considered.

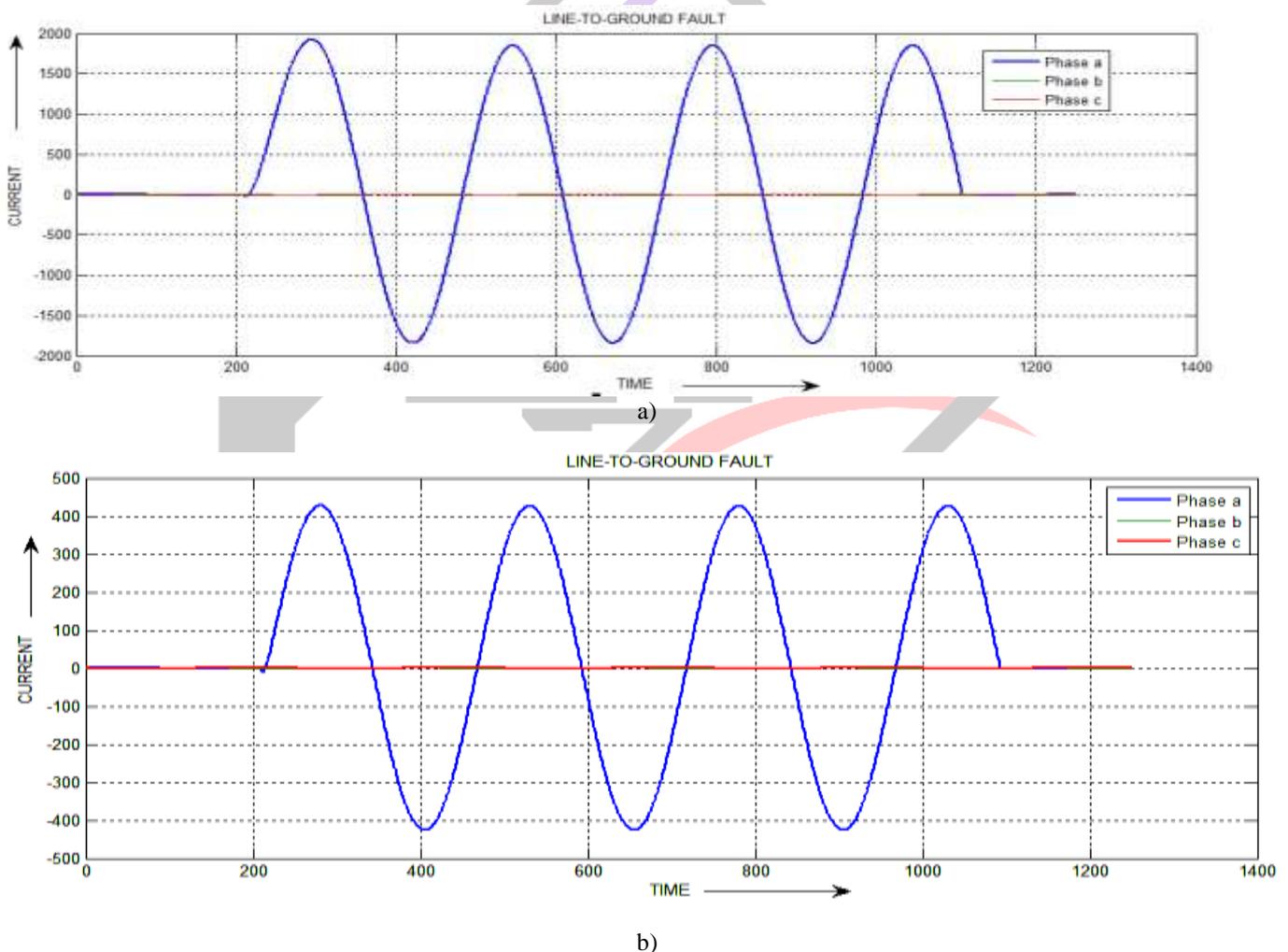


Fig. 6 a) LG Fault without SCFCL, b) LG fault with SCFCL

2) During double line-to-ground (LLG).

The following observations are made, under double line-to-ground fault before installing SCFCL. Simulation time of 0.1s is taken. At Current Waveform, Phase 'c' current is unaffected & found to be zero throughout the simulation period of 0.1sec. And phase 'a' and 'b' are zero up to 0.0168second. Afterward this time the current of the faulted phases 'a' and 'b' increases heavily

to 3690A and 3695A correspondingly. This condition continues until 0.0886sec after that all the phase currents approaches to zero.

During two line-to-ground fault without SCFCL, highest value of flaw current is about 3695A. With SCFCL, value of current is 490A. Hence SCFCL remarkably lowers the SC current value. Fig. 7a) represents current v/s Time during LLG fault without considering SCFCL and Fig. 7b) shows current against time variation with SCFCL. Power system approaches towards balance condition after installing Super conducting FCL.

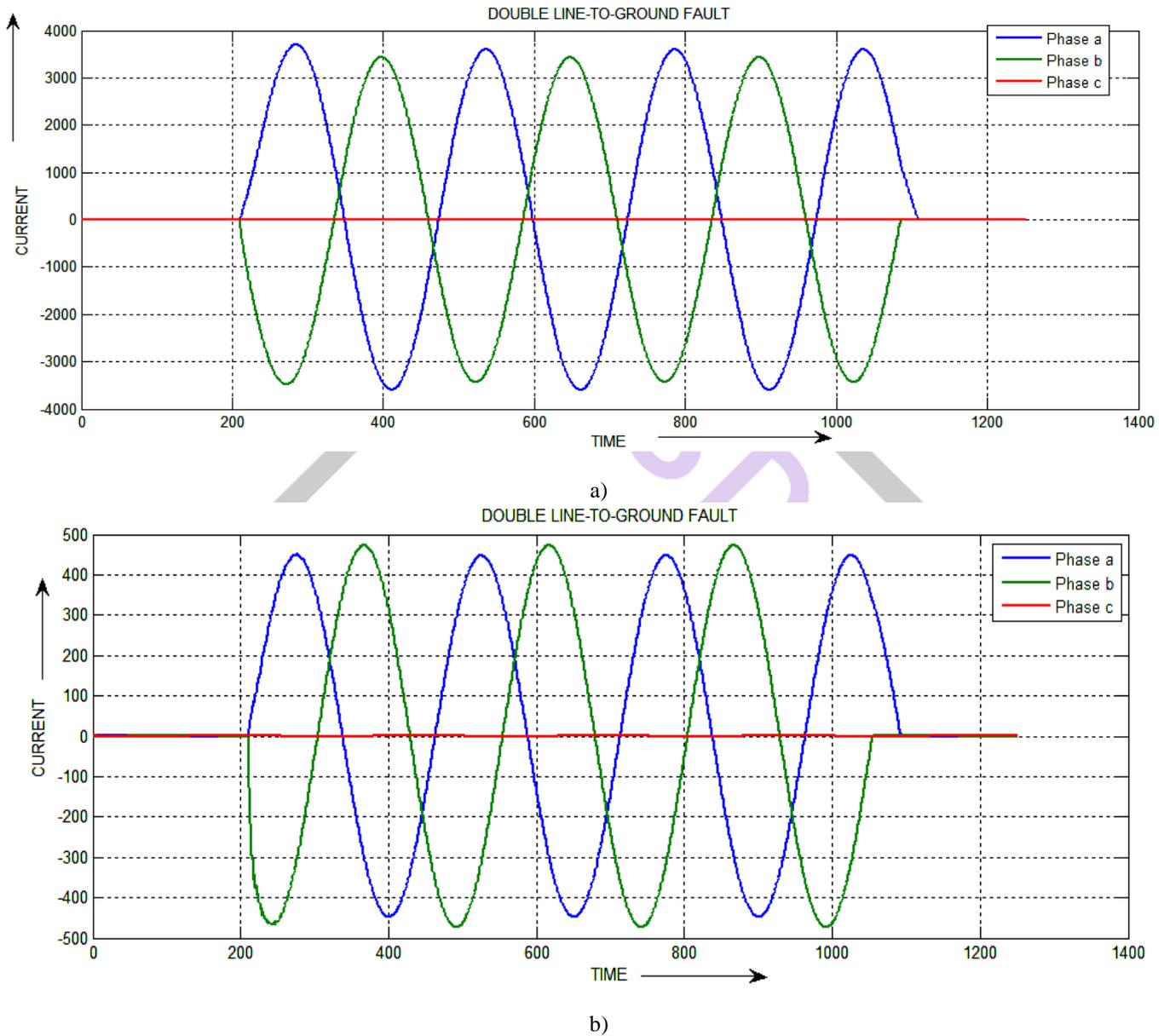


Fig. 7 a) LLG Fault without SCFCL, b) LLG fault with SCFCL

3) At Three line-to-ground fault

Figure 8 a) represents LLLG failure without employing SCFCL. It is seen that, during simulation time of 0.1sec, till 0.0168sec, the three phase currents close to zero. Far ahead this time the currents of an each phase grow up to 3996A. After 0.09sec all the 3 phase currents become to zero value.

Figure8 b) With SCFCL Up to 0.0168sec, the 3 phase currents are zero. Later this time the currents of all three phases become 495A. After 0.09sec every phase currents close to zero. Hence, SCFCL bring downs fault current value. SCFCL reduces the burden on the present equipment.

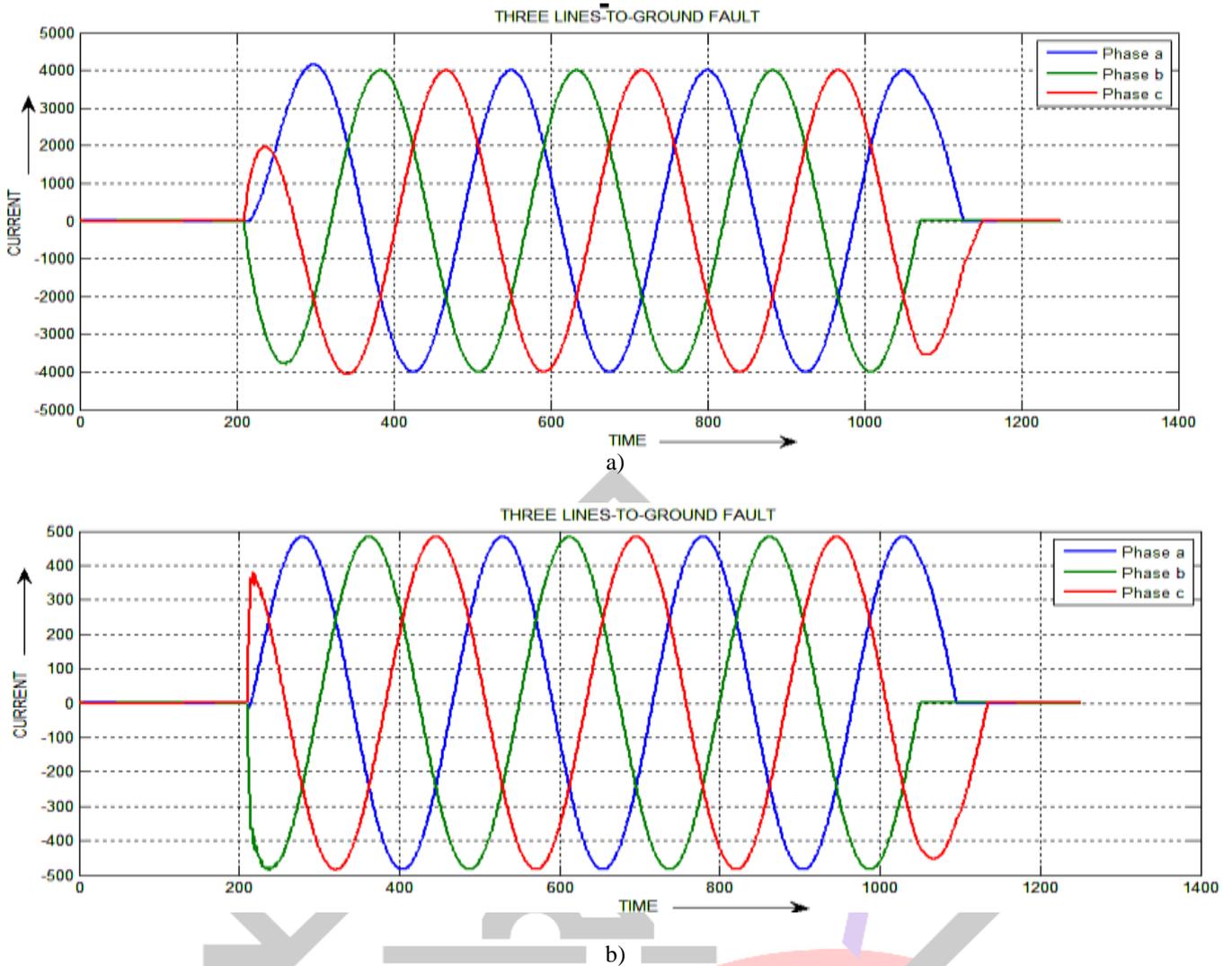


Fig. 8 a) LLLG Fault without SCFCL, b) LLLG fault with SCFCL

RESULTS: Fault was made at consumer side of the power plant. SCFCL shows good results in lowering fault current value. The outcomes are tabulated as below.

Table 3 Analysis of working of SCFCL under different fault situations

TYPES OF FAULTS	Magnitude of fault currents in Amperes	
	WITHOUT SCFCL	WITH SCFCL
L-G	1995A	425A
L-L-G	3695A	490A
L-L-L-G	3996A	495A

VII. CONCLUSION

Suddenly occurring short circuit faults may harm the power system devices. SCFCL will significantly lower the failure current value up to a predefined level during various faulty situations and releases burden on current switch gear components. SCFCL reduces the short-circuit current within 1st cycle. The proposed work dealt with the design of power system with and without resistive SCFCL module and the analysis was carried out for various fault conditions at distribution side of the electrical scheme by using MATLAB/SIMULINK.

The transitory rise in fault currents are limited up to more than 72% of the fault current using SCFCL comparing with without SCFCL scheme. By delivering the adequate value of resistance, the RSCFCL model has ability to limit the impulsive rise in fault current. The transient stability of the power system was improved. Life time of equipment's also improved by SCFCL. Thereby cost of switch gear devices can be decreased and also insulation levels of the network components were improved.

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