© 2015 IJSRST | Volume 1 | Issue 4 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

A Novel 110KV Fault Current Limiter for Improving The Reliability of A Substation

Kadir Ahmed Dafedar[1] , Waseem Ahmed Halwegar[2]
Dept of E&E, Anjuman institute of technology & Management, Bhatkal (Karnataka), India

ABSTRACT

In this paper, superconducting fault current limiter (FCL) is used as a novel technology for reducing the high fault currents and enhancing the security of 110kV substation. The model of 110kV substation is developed using the Matlab simulation program. The model is used to study at normal condition and short circuit analysis with the Matlab software. In the model of the FCL its major components, operation control algorithm, sequence of events and fault detection techniques are developed. The reduction of the fault currents are studied at the buses of suspected high fault currents by installing the FCL. The waveform obtained is for with and without FCL and comparison is done for the result. The transmission line is considered for the fault analysis using Fault Current Limiter with and without. The simulation results obtained have demonstrated the effectiveness of FCL in improving the system performance, reliability and security.

Keywords: Power system, substation, fault detection and system security, FCL, sequence activation algorithm, transient model.

I. INTRODUCTION

When electric power systems are expanded and become more interconnected, the fault current levels increase beyond the capabilities of the existing equipment, leaving circuit breakers and other substation components in over-duty conditions. Fault current arises due to line to line fault or line to ground fault (symmetrical or asymmetrical fault) in the power system. This fault results in sudden increase of current for small interval of time. Circuit breakers, sometimes, cannot handle the intense level of faults, so they fail to break the peak rest of fault current and is enough to burn the insulation and conductor. Handling these increasing fault currents often requires the costly replacement of substation equipment or the imposition of changes in the configuration by splitting power system that may lead to decreased operational flexibility and lower reliability.

To protect the electrical equipment the fault current should be reduced and normalized. The circuit breaker was before used to isolate the fault Section. If the fault current is more than interruption capacity of circuit breaker, it easily damages the electrical equipment in the circuit. An alternative is to use Fault Current Limiters (FCL) to reduce the fault current to a low acceptable level. So that the existing switchgear still be used to protect the power grid. So a new technology is adopted to reduce the fault current and to enhance the security of power system. This is the novel technique for reducing high fault current using high temperature super conducting fault current limiter (FCL). Now days the generation system has became more complex and more generation load is interconnected and control of fault current is done by splitting the power system into zones.

The FCL has several advantages for a critical utility problem with possible installation at interconnection, transformer, bus-tie, feeder closing open point and large industrial power point. A superconducting fault current limiter (FCL) will be operating in a superconducting state and is basically invisible to the power grid because no major energy loss and voltage drop will be developed across the device during normal operation. The FCL will produce a certain value of impedance within a few milliseconds due to the loss of superconductivity and insert it into the circuit, thus reducing the fault currents to levels that circuit breakers can handle.

Faults in power networks incur large short-circuit currents flowing in the network and in some cases may exceed the ratings of existing circuit breakers (CB) and damage system equipment The problems of inadequate CB short-circuit ratings have become more serious than before since in many locations, the highest rating of the CB available in the market has been used. To deal with the problem, fault current limiters (FCLs) are often used in the situations where insufficient fault current interrupting capability exists [1].

Several types of FCL have been designed with different superconducting materials. The resistive FCL is preferable because it increases the decay speed of the fault current by reducing the time constant of the decay component of the fault currents, and can also make the system less inductive. In 220kV/110kV/11kV the level of fault current is very high and can exceed the interruption capacity of the circuit breaker. The feasibility of the FCL for reducing the fault current levels, improving the system security and their impact on changing the operation network topologies is used in substation of and reduced the fault current to maximum level[2]. The FCL is considered to be one of the innovative devices of FACTS in electric power systems.

In this paper the modeling of 110 kV substations is carried out using Matlab / Simulink software. Simulation result obtained for fault currents at various lines likes line1, line2, line3 with and without incorporating FCL have been presented in this paper.

II. METHODS AND MATERIAL

A. Construction

FCL can generally be categorized into three broad types [3]. They are Passive limiters, Solid state type limiters, and Hybrid limiters. The FCL system in Fig. 1 [4] consists of six FCL modules arranged in a cryostat with suitable current leads and high voltage bushings and a cryogenic supply. The dimensions of the cryostat are approximately 2 m in diameter and about 5–6 meters in length, which nearly fits into the field size of a 110 kV substation. The FCL is designed and manufactured using MCP-BSCCO-2212 monofilar components. The ceramic tubular element (typically 50mm outer, 42mm inner diameter, 370mm length) were produced by melt cast processing and it is optimized to yield a material with T_c = 94k, J_c = 10 A/mm^2 and room temperature resistivity = 5m ohm-cm. Where T_c is critical temperature and J_c is current density. The final component is obtained by soldering brass or copper contact and a shunt of Cu-Ni alloy. These composites are reinforced with FRP and machined into 2 to 3m long monofilar coils. Two such coils are connected in series with a brass or copper pipe coupled. A typical HTS component has I_c = 600A and during the fault, it is subjected to a voltage of 150V. The cooling concept is based on a refillable LN_2 storage and for a vacuum pumps to control the nitrogen gas pressure and the temperature inside the cryostat is 65k. One component of the magnetic field triggered concept consists of a MCP-BSCCO 2212 tube with suitable copper contacts at both ends and a conventional coil that is wound directly onto the tube. The bifilar coils shown in Fig. 1[5] are made of MCP-BSCCO-2212 tube and have resistive property, magnetic field triggered concept is used for 110kV FCL and in this concept the high electrical field during limitation and very high rated current per HTS elements. A group of FCL component are made into modules shown in Fig.1 [5] of a certain rating and the components are fixed between two round plates made of epoxy-glass resin.

There is a small distance between the components to keep the copper connection short to minimize the AC losses in these connections. The component is made of spiral shape to have compact design and maximum electrical insulation length because the current is fed in the outer radius and is fed out in the middle of the spiral. An active length of each component is 40 cm and an electrical field during limitation of 3.2 V/cm. The entire assembly is placed in the cryostat with the nitrogen gas filled to quench the arc with pressure of 5 bar inside. The design value of the electrical field inside the cryostat is 40kV/cm at 5 bar. The 110kV FCL have 93 component per modules and it rating is designed for 11.83 KV_{rms} and 1850 A. the length of 110kV FCL of each component is 40 cms and electrical field during limitation is 3.2 v/cms. When the quench in the superconductor starts to develop the current commutates into the conventional coil and the magnetic field of the coil accelerates the quench. This function depends on the strong magnetic field dependence of the superconductor's critical current.

There are four different type of breakdown mechanism for high voltage FCL

- LN_2 breakdown
- N_2 breakdown
- Surface flashover
- Solid breakdown

The breakdown electrical field of N_2 at 1 bar and room temperature is 24 kV/cm and that the free length from high potential to ground for the 110kV voltage level at 1 bar is 1050mm. FCL is an innovative fault current limiter. It works on the principle of Superconducting Property. It is inactive under normal condition. It is in active under fault condition, it inserts some resistance into the line to limit the fault current. It suppresses the fault current within first half cycle only. It operates better than Circuit breakers, Relays, because the Circuit breakers takes minimum 2-3 cycles before they getting activated. The effect of SFCL on micro grid fault current observed. The optimal place to SFCL is determined [6].

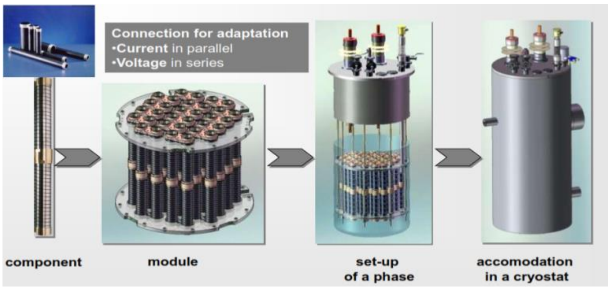

Figure 1. Construction of Fault Current Limiter

The assemble module of three phase 110 kV FCL as shown in Fig. 2 [7].

Figure 2: Drawing and complete 3-phase- FLC 12-800 system

B. Simulation Model of FCL

The resistive type FCL is modeled considering four fundamental parameters of a resistive type FCL. These parameters and their selected values are [8]: 1) Transition or response time = 2m.sec 2) Minimum impedance = 0.01Ω. Maximum impedance = 20Ω 3) Triggering current =550A 4) Recovery time = 10 msec. The FCL working voltage is 139kV. The maximum impedance value can be varied from 20 ohms to 27 ohms. The three phase FCL model developed in Simulink/SimPower System is shown in Fig. 3 and the single phase FCL model is developed to study single line network [9]. The FCL model works as follows. First, FCL model calculates the RMS value of the passing current and then compares it with the characteristic table. Second, if a passing current is larger than the triggering current level, FCL resistance increases to maximum impedance level in a predefined response time. Finally, when the current level falls below the triggering current level the system waits until the recovery time and then goes into normal state. Fig. 3. Simulink model of three phase FCL. The current limiting resistance value is calculated and this value is implemented in the simulation model. The important parameter to be given in FCL is the current limiting resistance value. The FCL model developed is tested in both single phase and three phase test systems and the current waveforms are recorded with the presence and absence of FCL.

The simulation model of a three phase test system with and without FCL and the current waveforms are recorded. The fault current is induced in the source directly in order to reduce the complexity of the simulation model. The type of the fault induced in the model is single phase to ground fault where it is induced through the AC voltage source. An RMS block is needed in order to calculate the RMS value of the incoming current signal and to increase the impedance value according to the limited fault current value specified in the FCL characteristic table. The performance of the FCL can also be tested in a power system generation and distribution systems using three phases FCL for controlling the fault current for each phase. Harmonics filtration is used in order to reduce the harmonics caused due to the abnormal fault current. A normal first order filter is used for reducing the harmonics. The type of the filter can be changed depending upon the application of the system. A controlled voltage source is connected in order to compensate the voltage sag caused due to the induced fault current which is caused due to both internal and external causes.

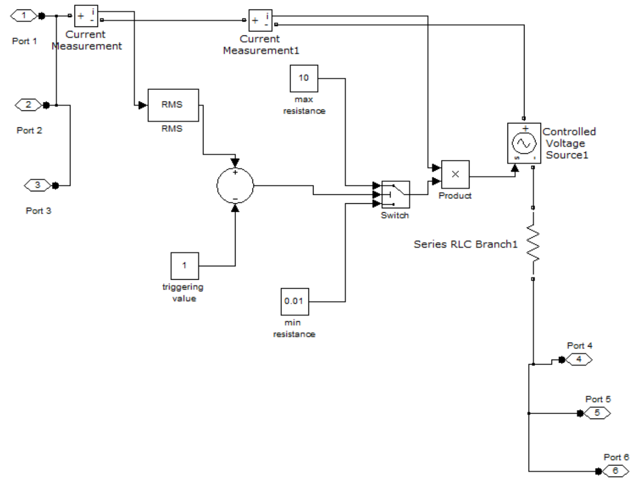

Figure 3: Simulink model of three phase FCL

C. Description of 110kv Substation

Single line diagram of 110kV substation is shown in Fig. 4. It consists of 110kV, 33kV, 66kV, 11kV transmission lines and incoming lines are 110kV. It is having various protection devices like circuit breaker and relays. The protection of substation devices is very essential to have good reliability of the power supply. The fault of symmetrical and asymmetrical is protected by relays and circuit breaker. During temporary or permanent fault, the circuit breaker trip and isolate the faulty area. This interrupt the supply and result in the loss of power to consumer and the reliability also decreases. It also affects the revenue of Power Corporation. If the fault is temporary, it should be cleared very quickly without isolating the consumer supply. The electrical equipments that are installed in the substation need to be protected from very large fault current.

The analysis and simulation is carried out with and without FCL using Matlab in 110kV substation. In this paper, an investigation has been carried out to limit the fault current in the event of temporary fault by installing FCL at suitable point in the substation.

The substation consists of four, 110kV transmission line and the substation is a ring system. It is connected to other substation so that in any occurrence of fault, power supply can be taken from other 220/110kV substation. It is automated and connected to 220kV substation through SCADA. All the parameter, contingencies, load control and maintenance schedule is obtained from local dispatch centre (LDC).

The four, 110kV transmission line are,

- Line1
- Line2
- Line3
- Line4

The 110kV transmission line is feeding residential, industrial, commercial and agricultural load. Often temporary and permanent fault occurs leading to interruption of power supply. During the temporary fault the loss can be minimized by using the FCL in switchyard. The fault current limiter should be connected in series with the circuit breaker. During the temporary fault the short circuit current is reduced to normal range and the process moves uninterrupted. There is no interruption of power supply, hence there is increased of reliability in power system. In the switchyard, the 110kV bus is feeding all the transmission line (except incoming lines). The transmission like is having protection device like distance protection relay, phase differential relay, circuit breaker(SF6), group operating system (GOS), lightning arrestor, spark gap. But this is not enough to protect the system from fault, so Fault Current Limiter (FCL) should be installed to protect the electrical equipment. Project model is made in Matlab, the four 110kV transmission line is considered. The Line1 110kV line is connected with Fault Current Limiter (FCL) and it is placed in series with the circuit breaker. The 110kV line of Line2 is connected to the load with circuit breaker but no FCL and 110kV line1 is without Fault Current Limiter and circuit breaker. All the 110kV transmission line is disturbed with the three phase fault and the simulation is observed with and without Fault Current Limiter (FCL).

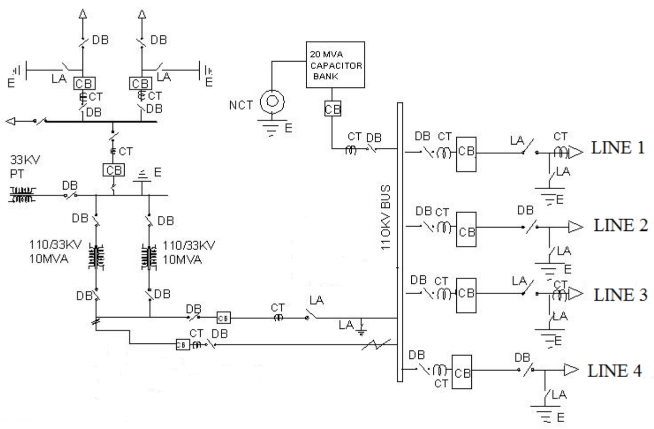

Figure 4: Single Line Diagram of 110 kV Substation

III. SIMULATION MODEL, RESULTS & DISCUSSION

The Fig. 5 shown consists of three branch of 110kV transmission line model in Matlab. The first, 110kV line1 is shown with FCL installed. Secondly the 110kV line2 is having circuit breaker in series with no FCL and third 110kV transmission line3 does not have circuit breaker or FCL connected to power system. The fault is made to occur at all the three branches separately and simulation is observed for all the branch.

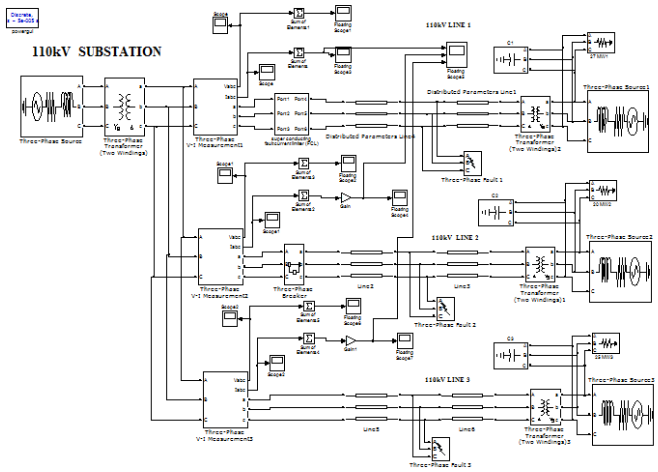

Figure 5 : 110kV substation model in Matlab

Simulation of 110kV transmission line3

The 110kV transmission line1 is connected with Fault Current Limiter (FCL) in series with the equipment. The fault is made to occur for 0.1 sec at certain distance from the switch yard and waveform is observed with and without Fault Current Limiter (FCL). The Fig. 6 below is the Matlab model of 110kV line1 with Fault Current Limiter (FCL).

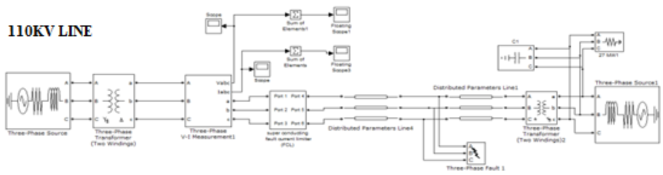

Figure 6 : Matlab model of 110kV line

Now Figure shown below are for asymmetrical fault Waveform recorded with Fault Current Limiter (FCL) connected to the transmission line and during the fault of Phase A with Ground fault current without FCL as shown in Fig. 7.

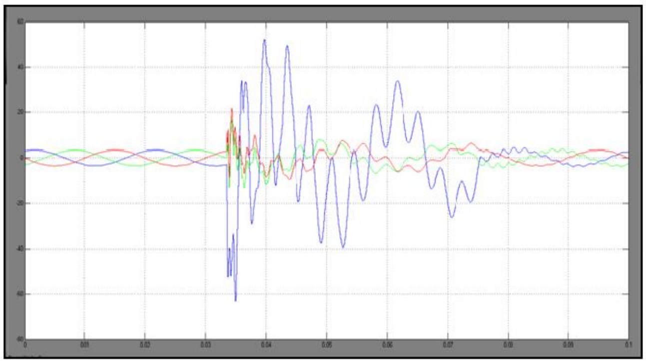

Figure 7 : Phase A to Ground Fault current without FCL

Fig. 8 is the waveform of phase A to ground fault current with FCL and it has reduce the fault current to normal value.

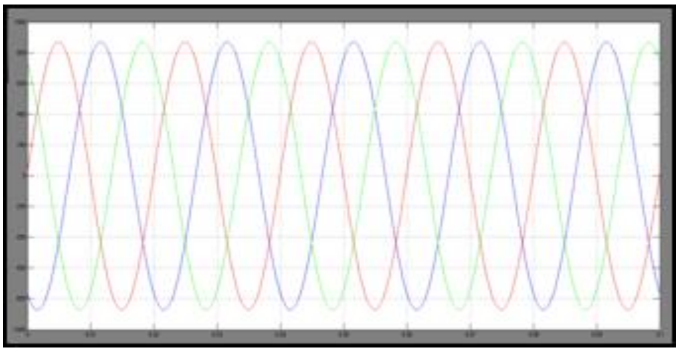

Figure 8 : Waveform during fault of Phase A to ground fault current with FCL

Phase B to Ground fault current is shown in Fig. 9 and FCL is not connected to the transmission line.

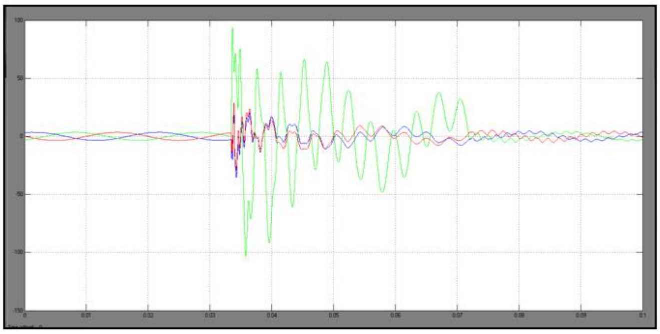

Figure 9 : Phase B to Ground fault current without FCL

In Fig. 10 waveform is recorded for phase B to ground fault current with FCL connected to transmission line.

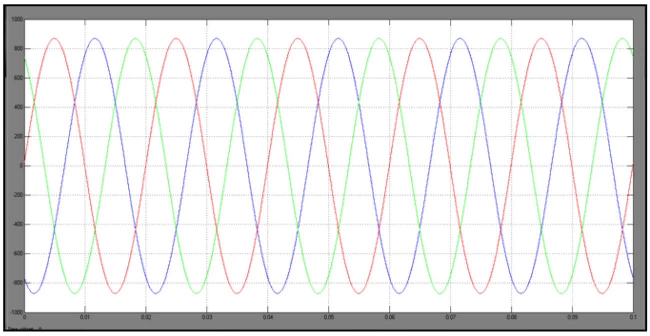

Figure 10 : Phase B to Ground fault current with FCL

Phase C to Ground fault current is shown in Fig. 11 and FCL is not connected to the transmission line.

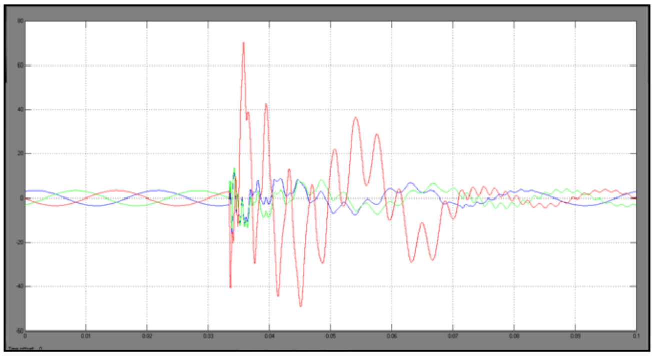

Figure 11 : Phase C to Ground fault current without FCL

In Fig. 11 waveform is recorded for phase C to ground fault current with FCL connected to transmission line.

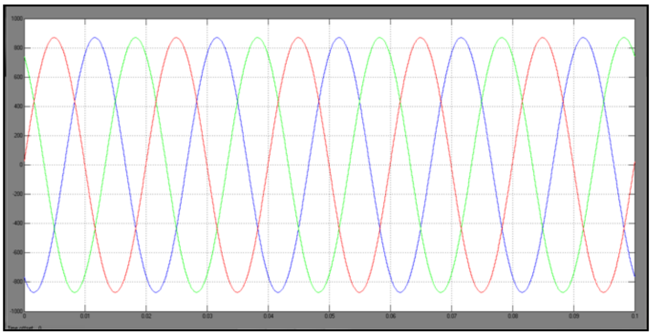

Figure 12 : Phase C to Ground fault current with FCL

Phase A,B,C to Ground fault current is done without FCL and the waveform Fig. 13.

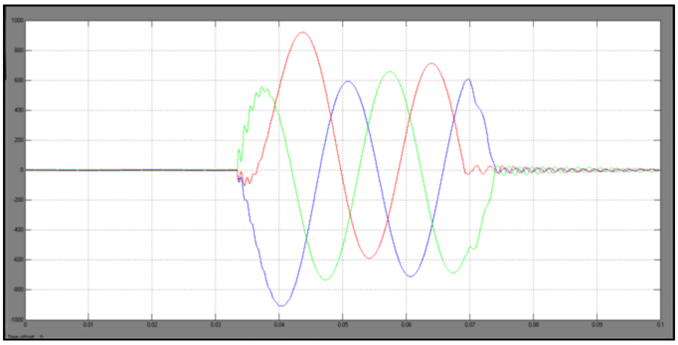

Figure 13 : Phase A,B,C to Ground fault current without FCL

FCL is connected and phase A,B,C is shorted with Ground and waveform recorded in Fig. 14 shown the normal value of fault current during the transient period.

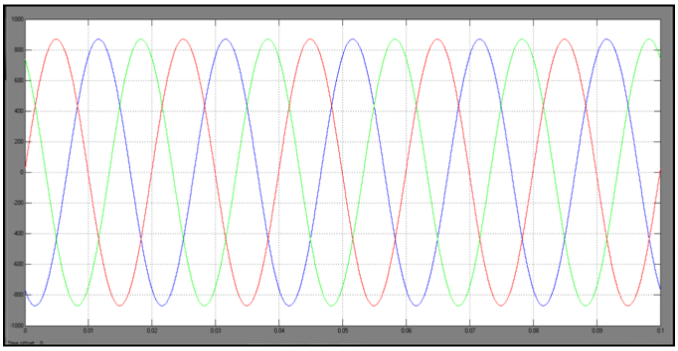

Figure 14 : Phase A,B,C to Ground fault current with FCL

Phase A,B,C is shorted as shown in Fig. 15 and FCL is not connected to the transmission line.

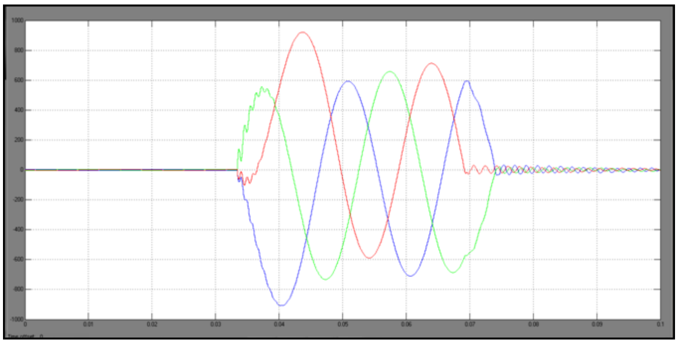

Figure 15 : Phase A,B,C is shorted without FCL

Fig. 16 the waveform observed when the short circuit has done with A,B,C and FCL is connected to transmission line.

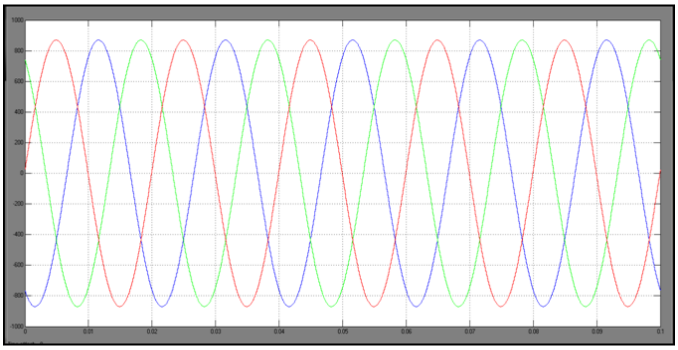

Figure 16 : Phase A, B, C is shorted with FCL installed

From the observation of the waveform, it is clear that the fault occurs and the only protection is circuit breaker. When FCL is connected to the transmission line, it reduces the fault current to normal value and system is protected from asymmetrical and symmetrical fault. Hence this system protection is only for temporary fault in the power system.

IV. CONCLUSION

This paper introduces the FCL as new technology for reducing the short circuit currents at the 110kV level of substation network. Therefore, the FCL improves the system security with minimum short circuit currents. Subsequently, improving the system reliability and minimizing the loading on the feeders in steady state and under contingency. The installation of FCL in the substation removes the temporary fault. The device is efficient in temporary fault and if permanent fault occurs the FCL does not play any role. So the development should be done to make FCL more operatable during permanent fault. Hence FCL can be installed in any substation to improve the reliability and to meet the demand of the consumer effectively.

V. REFERENCES

[1] P. G. Slade, et al, "The Utility Requirements for A Distribution Fault Current Limiters", IEEE Transactions on Power Delivery, Vol. 7, No. 2 April 1992 507-515.

[2] M. S. El Moursi, and Roshdy Hegazy “Novel Technique for Reducing the High Fault Currents and Enhancing the Security of ADWEA Power System”, IEEE Trans Power system, vol.28, no.1, Feb 2013.

[3] V. Manish, “Comprehensive overview, behavioral model and simulation of a fault current limiter,” Master of Science in Electrical Engineering thesis, Virginia Tech, Blacksburg, VA, 2009.

[4] Mathias Noe, Andrej Kudymow, Stefan Fink, Steffen Elschner, Frank Breuer, Joachim Bock, Heribert Walter, Martin Kleimaier, Karl-Heinz Weck, Claus Neumann, Frank Merschel, Bernd Heyder, Ulrich Schwing, Christian Frohne, Klaus Schippl, and Mark Stemmle “Conceptual Design of a 110 kV Resistive Superconducting Fault Current Limiter Using MCP-BSCCO 2212 Bulk Material,” IEEE Transactions on Applied Superconductivity, vol.17, no.2, June 2007.

[5] Naxan, Tenth EPRI Superconductivity Conference Mathias Noearlsruher Institut für Technologie & Joachim Bock, Achim Hobl, udith Schramm Nexans SuperConductors GmbH EPRI 2011 October11-13, 2011.

[6] Study of position of SFCL for maximum fault current limiter for power systems protection, Sachin Trankatwar, Dr.S.L.Nalbalwar, Dr. A.B.Nandgaonkar, International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July-2013 866 ISSN 2229-5518.

[7] J.Bock, M. Bludau,R.Dommerque,A.Hobl, S. Kraemer, M. O. Rikel, and S. Elschner, “HTS fault current limiters—First commercial devices for distribution level grids in Europe,” IEEE Trans. Appl. Supercond., vol. 21, no. 3, pp. 1202–1205, Jun. 2011.

[8] Analysis of Positioning of Superconducting Fault Current Limiter in Smart Grid Application S. Srilatha , Dr.K.Venkata Reddy PG-Student, Department of Electrical and Electronics Engg.JNT University, Kakinada, India Assistant Professor, Department of Electrical and Electronics Engg, JNT University, Kakinada, India, IJAIR.

[9] Kovalsky, L., Yuan, X., Tekletsadik, K., Keri, A., Bock, J. and Breuer, F., ”Applications of superconducting fault current limiters in electric power transmission systems,” IEEE Trans. on Applied Superconductivity, Vol. 15, No. 2, June 2005.

VI. AUTHOR'S DETAILS

1) Kadir Ahmed Dafedar received B.E degree in Electrical and Electronics from Karnataka University(KUD) Dharwad in the year 2001 and M.Tech in Power system from Visvesvaraya Technological University, Belgaum in the year 2014.He has published several research papers in the field of Electrical Engineering. Presently he is working as Assistant Professor in Department of Electrical & Electronics Engineering, Anjuman institute of technology and management, Bhatkal (Karnataka, INDIA). And his areas of interest are Renewable energy sources and power system protection.

2) Waseem Ahmed Halwegar received B.E degree in Electrical and Electronics from Visvesvaraya Technological University, Belgaum in the year 2010 and M.Tech in Digital Electronics from Visvesvaraya Technological University, Belgaum in the year 2013.He has published several research papers in the field of Electrical Engineering. Presently he is working as Assistant Professor in Department of Electrical & Electronics Engineering, Anjuman institute of technology and management, Bhatkal (Karnataka, INDIA). And his areas of interest are Power Electronics, Renewable energy sources and power system protection.