International Journal of Engineering Research & Management Technology ISSN: 2348-4039
January-2016 Volume 3, Issue-1
Email: editor@ijermt.org www.ijermt.org

A Novel Approach of Superconducting Fault Current Limiter to A Single Phase Power System

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ABSTRACT:
In this paper, an application of superconducting fault current limiter (SFCL) is proposed to limit the fault current that occurs in power system, SFCL is a device that uses superconductors to instantaneously limit or reduce unanticipated electrical surges that occur on utility distribution and transmission networks. When a fault occurs in the line, a large surge of power is sent through the grid. This surge results in damage to expensive grid-connected equipment. SFCL's greatly reduce the financial burden on the utilities by reducing the wear on circuit breakers. A single phase power system is integrated by usingsimulink and SimPowerSystem blocks in Matlab. The simulated network has three ac voltages sources (230V, 50Hz), Pi section lines and few single phase loads of 1KW, 2HP, 1.5KW and 2HP. A fault current test is made with super conducting fault current limiter. The complete analysis of SFCL has been done by this test in operating the power system under normal condition, then a LG fault condition and further the fault current limiting done by SFCL. The simulation results show that the SFCL can play an obvious role in restraining the fault currents. Thus Power distributors can eliminate the cost of circuit breakers and fuses by installing SFCL’s in the grid.

INDEX TERMS: fault current, super conducting fault current limiter, LG fault and load currents

I. INTRODUCTION:

The conventional protection devices installed for protection of fault current in electric power systems are the circuit breakers tripped by over current protection relay which has a response time delay that allows initial two or three fault current cycles to pass through before getting activated. But, Superconducting Fault Current Limiter (SFCL) is innovative electric equipment which has the capability to reduce fault current level within the first cycle of fault current. The first-cycle suppression of fault current by a SFCL results in an increased transient stability [1] of the power system carrying higher power with greater stability. Smart grid is the novel Term used for future power grid which integrates the modern Communication technology and renewable energy resources for the 21st century power grid in order to supply electric power [2] which is cleaner, reliable, resilient and responsive than conventional power system. Solving the problem of increasing fault current in micro grids by using SFCL technology [3] is the main topic of this work.

Up to now, there were some research activities discussing the fault current issues of smart grid, but the applicability of SFCLs into micro grids was not found yet. The utilization of SFCL in power system provide the most effective way to limit the fault current and results in considerable saving from not having to utilize high capacity circuit breakers Superconducting fault current limiters utilize superconducting materials to limit the current directly or to supply a DC bias current that affects the level of magnetization of asaturable iron core. While many FCL design concepts are being evaluated for commercial use and improvement in superconducting materials over the last 20 years have driven the technology to the forefront. Case in point, the discovery of high temperature superconductivity (HTS) in 1986drastically improved the potential for economic operation of many superconducting devices.

This improvement is due to the ability of HTSmaterials to operate at temperatures around 70Kinstead of near 4K, which is required by conventional superconductors The advantage

is that refrigeration overhead associated with operating at the higher temperature is about 20times less costly in terms of both initial capital cost and Operation &Maintenance costs.

This paper focuses on the testing of SFCL to a single phase power system and the percentage reduction of fault current is calculated by simulation results.

II. SIMULATION STUDY:

A single phase power system consists of three ac voltages sources (230V, 50Hz), Pi section lines, single phase loads of 1KW, 2HP, 1.5KW and 2HP are considered for a case study. The simulated model of single phase power system is shown in the Fig.1with appropriate current locations. A power system simulation tool is used to design[4] which consists of sources, pi section lines, loads with current measurements at different locations. In the simulation setup three conditions are taken for study, first in normal condition where there is no fault, Second is the fault condition where a LG(Line to Ground) fault is considered on the system without SFCL and third condition is the LG fault current reduction using SFCL in the system.Matlab/simulink/simpowersystem was selected to design and test SFCL. The software has open architecture, a powerful graphical user interface, versatile analysis and graphical tools.

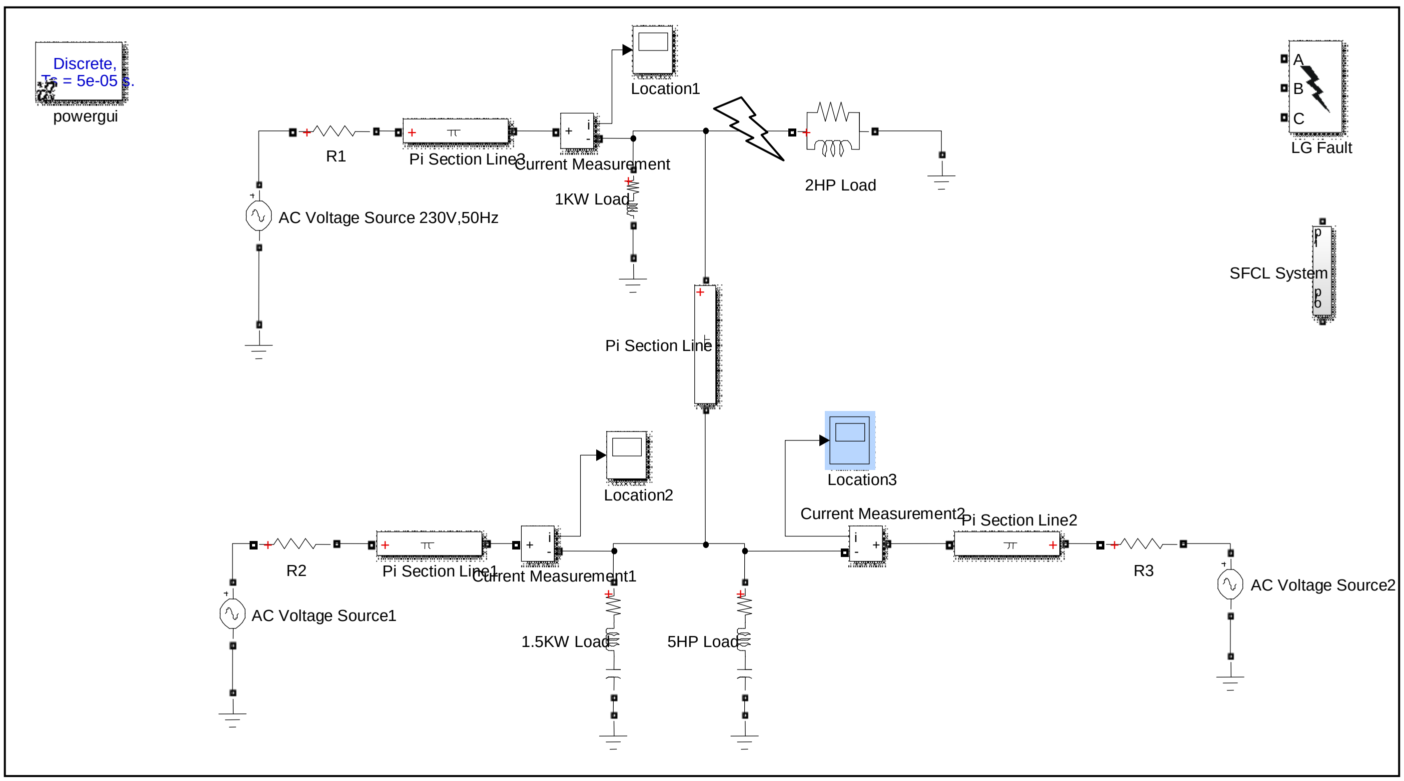


Fig.1. Simulated single phase power system

III. SINGLE PHASE SUPERCONDUCTING FAULT CURRENT LIMITER (SFCL):

The SFCL model [5] developed in Simulink/SimPower System is shown in Fig.2

The Simulink model was composed of four major parts [6]:

1. RMS value block
2. Characteristic table/look up table of SFCL
3. Harmonic Filtration by first order filter

4. Voltage controlled oscillator (VCO)

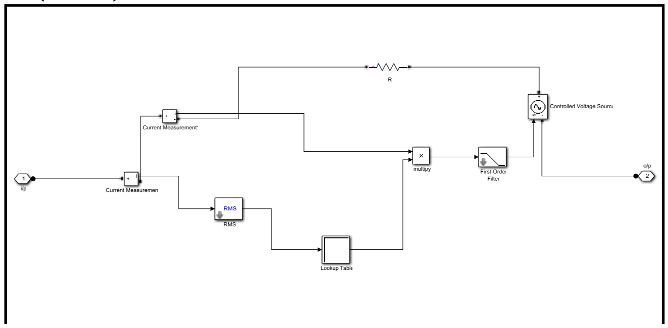


Fig.2. Simulated single phase SFCL

The parameters for the Resistive SFCL model and their selected values are:

1. Transition or response time = 2msec
2. Minimum impedance = 0.01Ω.
3. Maximum impedance = 20Ω
4. Triggering current = 11A and
5. Recovery time = 10msec.

The SFCL working voltage is 230V.

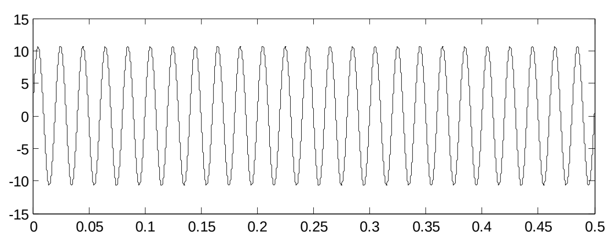
First, SFCL model calculates the RMS value of the passing current and then compares it with the characteristic table. Second, if a passing current is larger than the triggering current level, SFCLs resistance increases to maximum impedance level in a pre defined response time. Finally, when the current level falls below the triggering current level the system waits until the Recovery time and then goes into normal state. The SFCL characteristic/lookup block shown in Fig.2 which play a major role and consists of standard parameter values of SFCL. The current limiting resistance value is calculated and this value is implemented in the simulation model. The important parameter to be given in SFCL is the current limiting resistance value. It is stored in the SFCL characteristic table. In order to avoid harmonics caused by transients, first order filter is used in the limiter.

IV. CASE STUDY:

A. UNDER NORMAL CONDITION:

Under normal condition the currents are observed to be 10.73A. 10.69A and 10.60A as per Fig.3, these are the normal currents without any fault in the system, if any fault is occurred in the system then system is in abnormal condition. For the above shown Location outputs:current (Amperes)Vstime (seconds) are plotted as follows.

There will be sudden change in the magnitude of currents in fault period.All current wave forms are pure sinusoidal with 50Hz frequency under normal condition.



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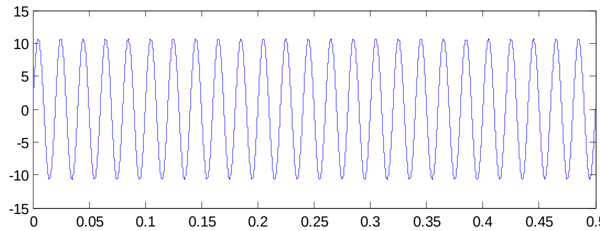

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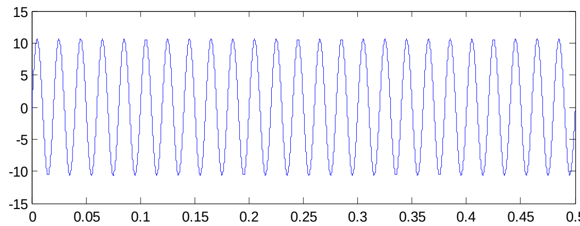
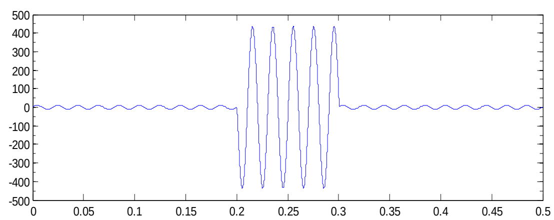


(c)

Fig.3. Currents under normal condition (a) current at Location1 is 10.73A (b) current at Location2 is 10.69A (c) current at Location3 is 10.60A

B. UNDER FAULT CONDITION:

For the power system a LG fault is applied at the fault location shown in Fig.1 and simulated within the fault period of 0.2 to 0.3seconds.The fault currents are observed Fig.4 at different Locations.When the fault is applied nearer to the source, then atLocation1 current raised from 10.73A to 435A. Similarly the Location 2 fault current is raised from 10.69A to 219A and the Location 3 fault current is raised from 10.6A to 219A.Since the fault is nearer to the source1, the magnitude of fault current is more (435A) in Location1.



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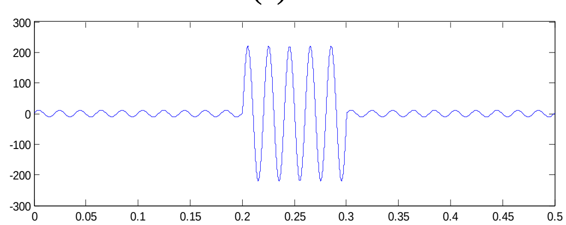

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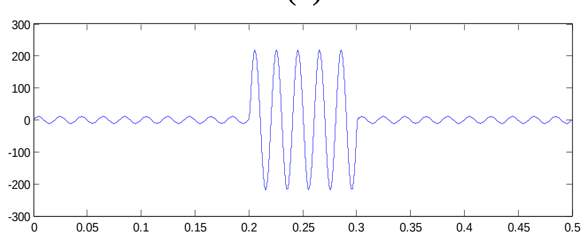


(c)

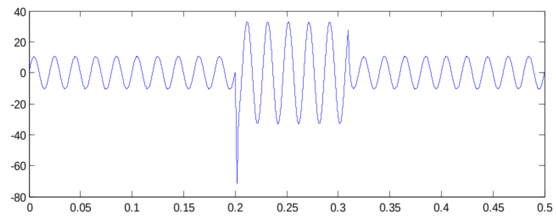
Fig.4. Currents under fault condition (a) Fault current at Location1 is 435A (b) Fault current at Location2 is219A (c)Fault current at Location3 is219A

It is observed that the system is in abnormal condition the fault currents need to be recovered by a fault current limiter.

C. WITH SUPER CONDUCTING FAULT CURRENT LIMITER:

The Super conducting fault current limiter was placed in the power system in a tie line, the fault currents are observed Fig.5 in Location 1 was 435A which is limited to 33A in the first cycle of fault current. Similarly fault current in Location 2 was 219A which is limited to 42A and Location 3 fault current from 219A is suppressed to 38A.

The current wave forms obtained after placement of SFCL in the grid are as below:



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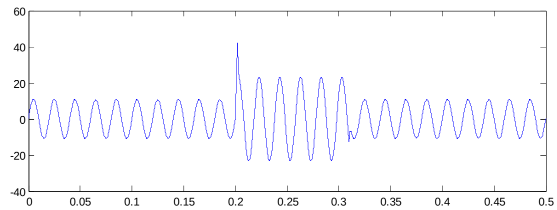

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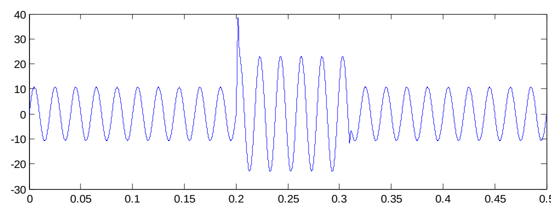
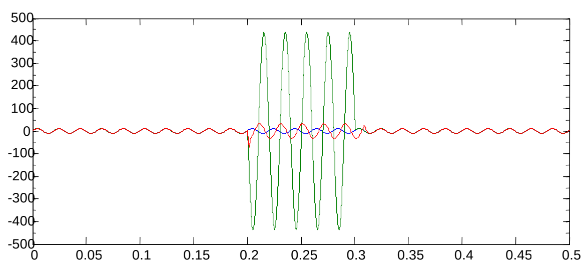


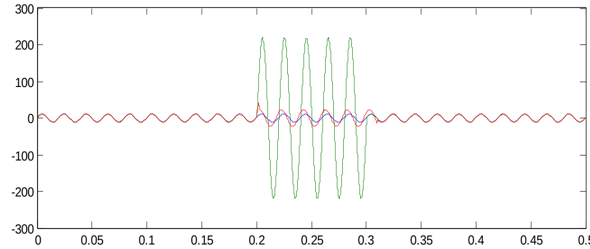
(c)

Fig.5. Currents with SFCL Placement in power system (a)Fault current reduced from 435A to 33A at Location1 (b)Fault current reduced from 219A to 42Aat Location2 (c)Fault current reduced from 219A to 38A at Location3

Further the combined waveformsfor three conditions of power system, that is the normal condition, the fault condition then fault recovery with SFCL are studied. Thus percentage decrease in fault currents are calculated from Fig.6.



(a)



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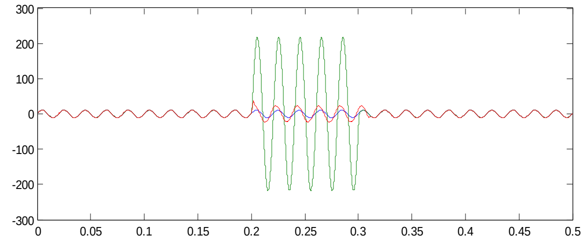

(c)

Fig.6. Fault current percentage reduction with placement of SFCL (a) Location1 is 92.41% (b) Location2 is 80.82% (c) Location3 is 82.64%

V. TEST RESULTS:

For the above considered single phase power system, the currents in 3 different Locations are obtained under normal, faulted and with SFCL conditions [7]. The current decreased in first cycle of fault current with SFCL is tabulated below.

TABLE I
MAGNITUDE OF CURRENT:

Power system operation under	LOCATION 1	LOCATION 2	LOCATION 3
a. Normal condition	10.73A	10.69A	10.60A
b. Fault condition	435A	219A	219A
c. With SFCL	33A	42A	38A

From the above result analysis it is clear that the SFCL test for a simple single phase system have reduced the magnitude of the fault current in the first cycle itself and thus fault current suppression [8] is achieved.

VI. CONCLUSIONS:

In this paper, the application of SFCL to a single phase system is investigated. The test results in percentage decrease of fault currents at different locations have been studied. The optimal position of placement of SFCL is at tie line. The work is applied to Distribution System (DS), where the occurrence of LG faults is more in number. The reliability of DS is improved. In recent years, more and more dispersed energy sources, Such as wind power and photovoltaic solar power are installed Into distribution systems. Therefore, the study of a coordinated Control method for the renewable energy sources and the SFCL becomes very meaningful. Power distributors can eliminate the cost of circuit breakers and fuses by installing SFCL's in the grid.

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The percentage reduction of fault currents at location1 is 92.41, at location2 is 80.82 and at location3 is 82.64.there is a great suppression of fault current in the first cycle itself.