

Analysis and Positioning of a Superconducting Fault Current Limiter in a Power System

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Abstract: Now-a-days, the main energy supplier of the worldwide economy is fossil fuel. However it has led to many problems such as global warming and air pollution. Therefore, with regard to the worldwide trend of green energy, renewable energy has become most promising energy resource. In order to supply more efficient, reliable, resilient and responsive electric power, micro grid will integrate main power grid and renewable energy resources. But due to the integration of renewable energy resources with the main power grid results in higher fault currents. To limit these fault currents, there is need of fault current limiters.

In this work, 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 may occur on utility distribution and transmission networks. Due to the difficulty in power network reinforcement and the interconnection of more distributed generations, fault current level has become a serious problem in transmission and distribution system operations.

The utilization of fault current limiters (FCLs) in power system provides an effective way to suppress fault currents and results in considerable saving in the investment of high capacity circuit breakers. In this work, a feasibility analysis of the positioning of a superconducting fault current limiter in a power system has been presented. A resistive type SFCL model is implemented by integrating Simulink and SimPowerSystem blocks in MATLAB. The power system which consists of a main power grid and a wind farm is modeled and the transient analysis is performed with the SFCL placed at different locations for three phase to ground faults at various locations. Finally the feasible location of the SFCL in a power system has been suggested.

I. I.INTRODUCTION:

General Power System:

In general, electrical power system consists of generators, circuit breakers, transformers, transmission line and etc.

In general an electrical power will be produced in large power plants using synchronous generators.

This power production will be nearer to the sources available, that is coal mines and abundant water that is required in power production.

- The generated power has to be supplied to the using consumers. This will be done using over head or underground transmission systems.
- The transmission of power will be done at high voltages and distribution will be done at low voltages.
- To supply the power to the consumers, it has to be passing through 3 stages, i.e. 1. Generation, 2. Transmission and 3. Distribution.

Distributed Generation (DG):

DG's possess more advantages when compared to general power system.

- Power quality of the power system will be improved a lot and also the voltage will be maintained constantly, as the customer needed. This interconnection will also helps to the power system to withstand to heavy loads.
- The Reliability of the power will be increased and the losses which occurred due to transmission will be limited. As the consumer expects the reliable and low losses of the power.
- The environmental problems will be reduced and the affect of green house gases will also be reduced.

Even though there are number advantages, there are so many drawbacks also there those are:

- Due to the integration/interconnection of DGs to the grid leads to miss matches in the protection equipment, voltage issues may occur and extra equipment has to be installed.

- The DGs will be interconnect using AC/DC converters which or power electronic devices. Causes harmonics production and also not economical.
- The fault currents will be changed due to the interconnection and identification of faults and quick action to the faults is becoming a challenge to the power system engineers.
- If the high impedance faults occur in the system, digital relays with fault current limiters should be used, which may be complex procedure.

Fault current limiting techniques:

By using High Impedance Transformers, the fault current/short circuit may be limited to a certain level. Even though there is reduction in abnormal current, there is an unexpected affects on the voltage profile and transient stability of the power system.

SSFCL (Solid State Fault Current Limiter) these limiters are uneconomical. Why because the power electronic devices has to be used as a switches. And also these solid state limiters are used only for distribution systems only.

Current Limiting Reactors which will reduce the fault current by offering the inductive reactance as impedance .There are two types of reactors depends upon the type of core, those are: Iron core reactors and air core reactors. Due to the core saturation, the iron core reactors are not used for most of the industrial purposes. Air core reactors are used for large industries and for power systems.

Superconducting technology is a new technology used for fault current limitation. Superconducting Fault Current Limiters (SFCL) are the new ones which are going to limit the fault current within first half cycle of the fault current.

II. SIMULATION DETAILS:

Matlab/Simulink/SimPowerSystem was selected to design and implement the SFCL model. Simulink/SimpowerSystem has number of advantages over its contemporary simulation software (like EMTP, PSPICE) due to its open architecture, a powerful graphical user interface and versatile analysis and graphics tools. Control systems designed in Simulink can be directly integrated with SimPowerSystem models

SIMULATION MODEL OF THE POWER SYSTEM:

The micro grid has been designed by integrating a 10 MVA wind farm with the distribution system. The power system is simulated with a 100 MVA conventional power plant, here the conventional power plant is a 3-phase synchronous machine. This is connected with a 154 kV, 200 km long transmission line. Here the parameters are distributed type. The voltage is stepped down kV from 154 kV to 22.9. There is a 6 MW Industrial load and three 1 MW domestic loads are being powered by separate distribution branches. The 10 MVA wind farm is designed with five fixed-speed induction generators, each induction generator have a rating of 2MVA.

Four eventual locations are considered for the installation of SFCL. Location 1 is considered as Substation, Location 2 is considered as Branch Network, Locations 3 is considered as integration point of the Wind farm and Location 4 is considered as Wind Farm. In general the traditional protection devices will be placed at location 1 and location 2. The output current/fault current contribution of wind farm for different locations of SFCL will be measured and analyzed in the following Sections to determine optimal position of the SFCL.

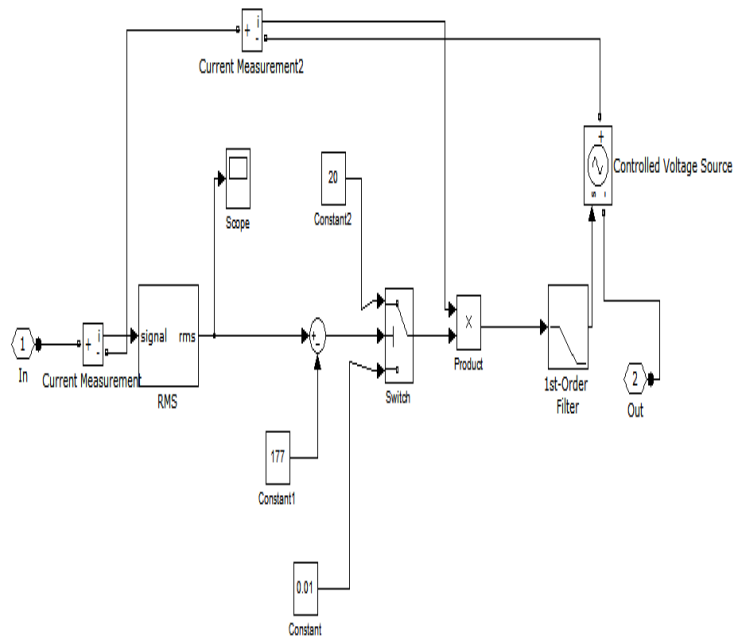


Fig 1: Simulation model of the Single Phase SFCL Model

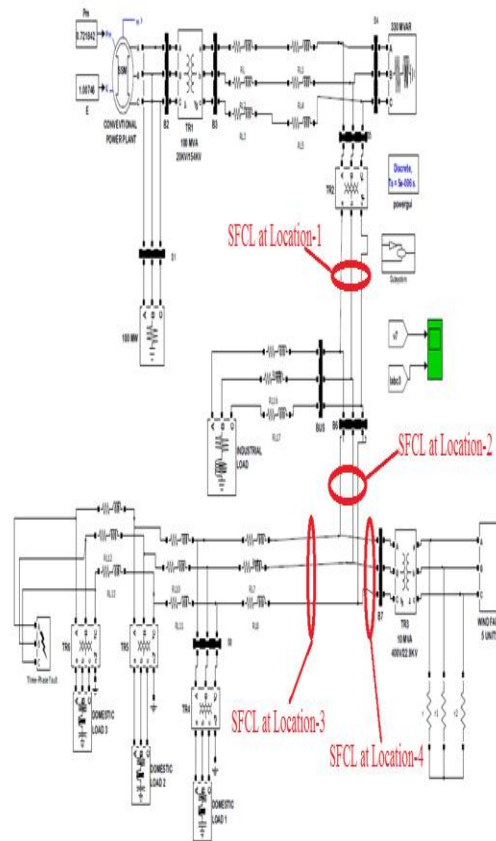


Fig 2: Simulation diagram of the power system with SFCL Locations

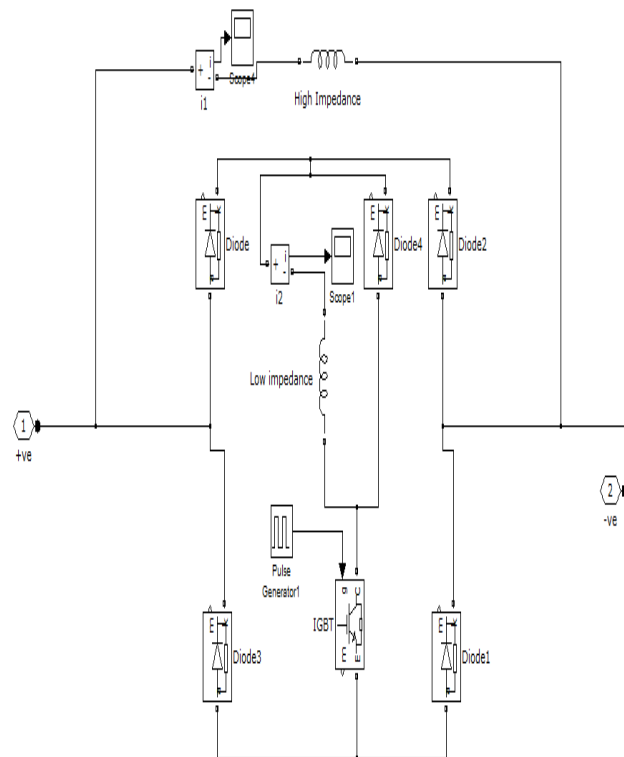


Fig 3: Single Phase FCL Model

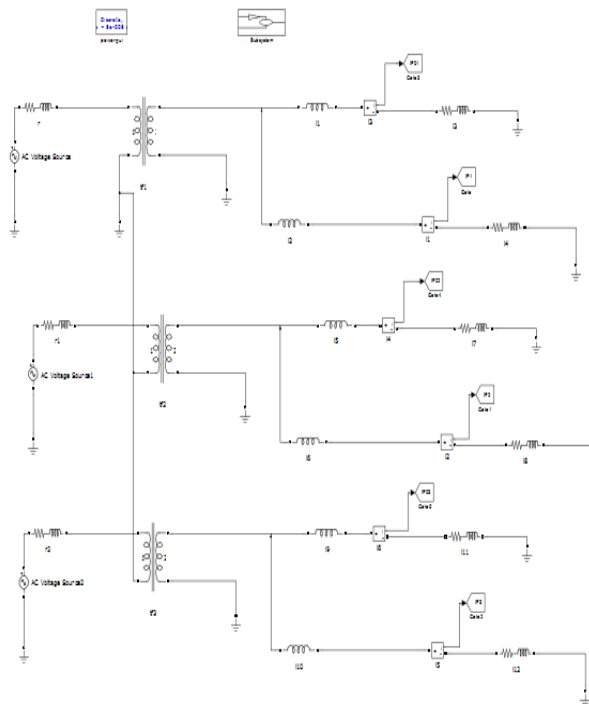


Fig 4: Small Power System under normal condition

Performance comparison has been done using conventional FCL model and SFCL model for a variety of faults at different locations. Both the models have been given in Fig 1 and Fig 4.

III. SIMULATION RESULTS:

Fault in the Distribution Grid:

In both the cases the SFCL located at Location 1, substation or Location 2, branch network, short circuit current contribution by the wind farm was increased and the magnitude of the short circuit current is higher than that of the ‘No FCL’ case. These observations describing that the installation of the SFCL at Location 1 and at Location 2, instead of decreasing the short circuit current has been increased. This unexpected rise in short circuit current by the wind farm is caused by the sudden change of power system impedance. The SFCL at Location 1 or Location 2 will limit the short circuit current coming from the conventional power plant due to sudden rise in the resistance. Therefore, the wind farm which is nearer to the Fault 1 will supply the larger fault current to fault point.

The case in which the SFCL is installed at the integration point of the wind farm with the main grid, indicated as Location 3, the wind farm short circuit current will be reduced successfully. Here the SFCL gives 68% reduction of short circuit current by the wind farm and also decreases the short circuit current contribution by the conventional power plant. Why because the SFCL is placed in the common path of the both the currents flowing towards Fault point, Fault 1.

By the installation of two SFCLs at Location 1 & 4, 45% reduction in short circuit current is observed. Even though there are two SFCLs installed, the wind farm short circuit current reduction is lower than that was attained by one SFCL installed at Location 3, integration point. We can observe that from the simulation results, the installation of two SFCLs Location 1 and 4 is technically and economically not feasible.

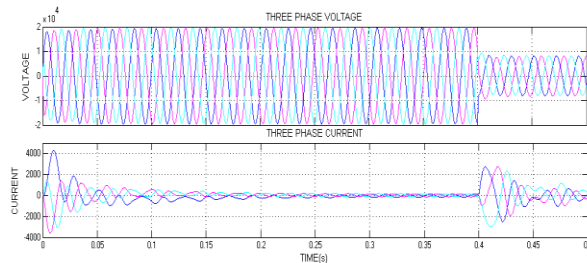


Fig 5: Under No Fault Condition

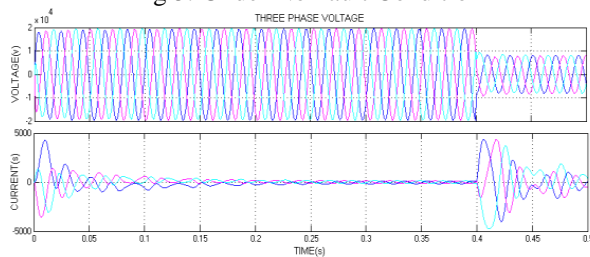


Fig 6: SFCL at Location 1

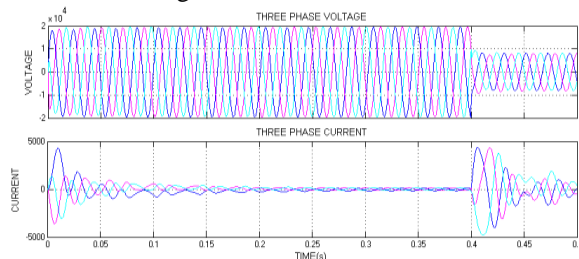


Fig 7: SFCL at Location 2

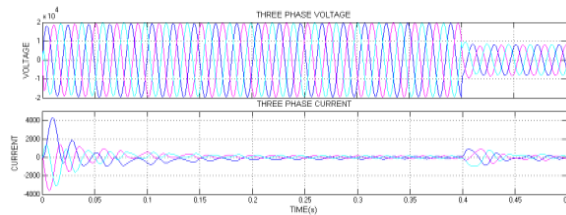


Fig 8: SFCL at Location 3

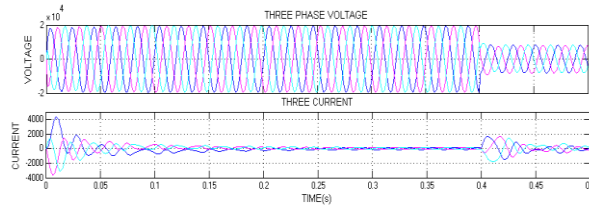


Fig 9: SFCL at Location 4

Fault in Customer Grid:

This fault is comparatively a small fault. Since it has been occurred in the low voltage distribution line, the results achieved are similar to that were observed for distribution grid fault.

Here also the better results are achieved for installation of single SFCL at Location 3 (integration point).

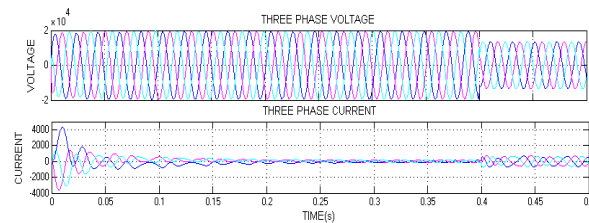


Fig 10: Under No Fault Condition

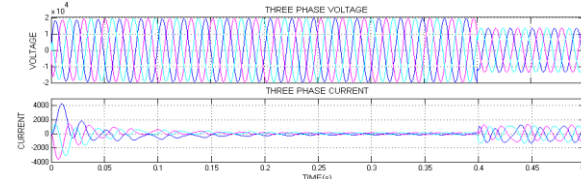


Fig 11: SFCL at Location 1

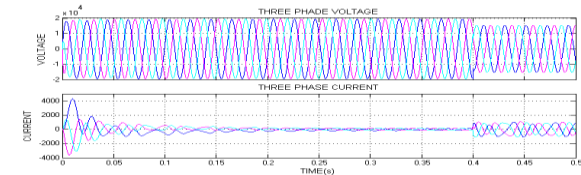


Fig 12: SFCL at Location 2

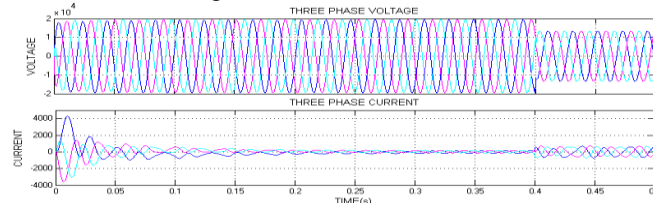


Fig 13: SFCL at Location 3

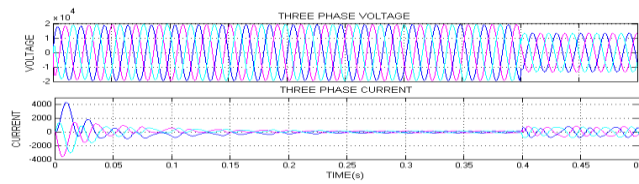


Fig 14: SFCL at Location 4

Fault in Transmission Line:

When a short circuit occurred on transmission line, the short circuit/fault current will be more when compared to previous two faults (Fault-1 & Fault-2).

As the short circuit occurred on a high voltage transmission line the short circuit/fault current will be more. The results obtained are different when compared to previous cases (Fault-1 & Fault-2). Here, the SFCLs placed at Substation and Branch Network decreases the wind farm short circuit/fault current.

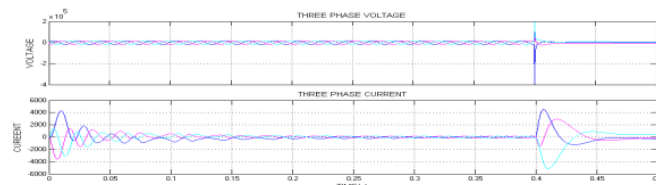


Fig 15: Under No Fault Condition

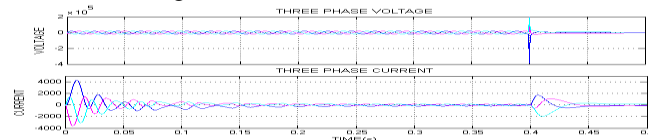


Fig 16: SFCL at Location 1

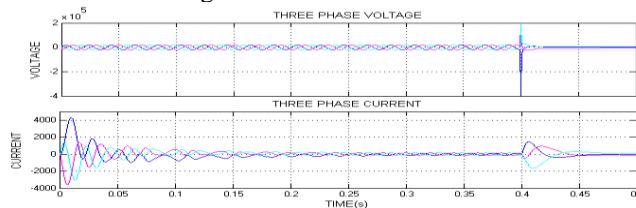


Fig 17: SFCL at Location 2

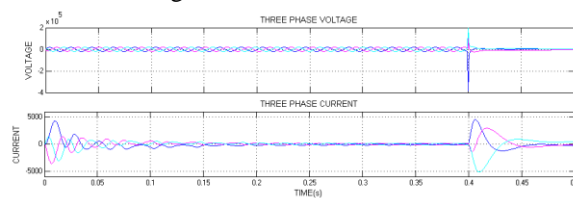


Fig 18: SFCL at Location 3

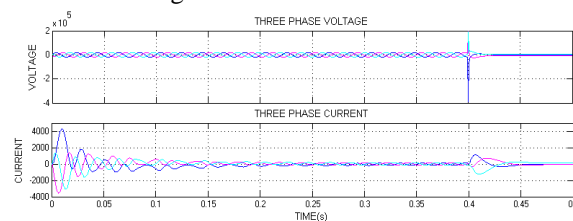


Fig 19: SFCL at Location 4

IV. CONCLUSION:

In this work, a feasibility analysis of the positioning of a superconducting fault current limiter in a power system has been presented. The power system which consists of a main power grid and a wind farm was modeled and the transient analysis was performed with the SFCL placed at different locations for three phase to ground faults at various locations. From the simulation results, it has been observed that the SFCL should not be placed at the Substation or Branch network directly. This installation of SFCL results in unusual short circuit current contribution by the wind farm. Multiple SFCLs in power system are inefficient both in cost and performance. The feasible location of SFCL in a power system which limits all short circuit/fault currents is the point of integration of the wind farm with the main power grid.

Future Scope

SFCL limiter can be implemented for the protection of the batteries/energy storage devices. The voltage sags which occur due to the faults or over loads may be compensated by using the SFCL. To identify the feasible location of SFCL different optimization-techniques may be used for large and complex power systems.

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