International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 06 | Sep-2015 www.irjet.net p-ISSN: 2395-0072

# SFCL PREVENT DISTRIBUTED GENERATING SOURCES FROM BLACKOUT IN SMART GRID

**Aakash P. Patil[1], Ajit P. Chaudhary[2], Gaurav P. Tembhurnikar[3]**

[1] *ME Student, Department of Electrical Engineering, SSGBCOET Bhusawal, Maharashtra, India*
[2] *Associate Professor & Head Department of Electrical Engineering, SSGBCOET Bhusawal, Maharashtra, India*
[3] *Assistant Professor, Department of Electrical Engineering, SSGBCOET Bhusawal, Maharashtra, India*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract -** ***To prevent distributed generating sources from Blackout in smart grid system SFCL can be implemented. To enhance the reliability of the power system, interconnection of the distributed generating (DG) sources is required with the existing electrical grid. Presence of fault current due to extensive integration of DG sources within a smart grid causes failure of a successful implementation of smart grid. All running power plant are synchronized with each other in main power grid and continuously generating power and delivered to the grid. All conventional power plants are also connected with DG sources in grid and running in synchronized condition, if any fault will occur in system then the system will be unstable and which will affect DG sources found nearest location of fault. DG sources get Blackout, so to avoid from blackout condition one of the best innovative solution is to implement SFCL at optimum location in system. SFCL have capability to reduce the fault current level within the first cycle of fault current, which result in an increased in transient stability of the power system. A resistive type SFCL model has been developed in Simulink and the SFCL performance will analyses for different location. Location 1(near Substation). Second, single SFCL located at Location 2(near Branch Network). Third, single SFCL located at Location 3(near Wind farm integration point with the grid). Fourth, double SFCLs located at Location 1(Substation) and Location 4(Wind Farm) in the proposed system considering 10 MVA wind farm as a DG sources with synchronized big units as conventional power plant of 100 MVA. A Simulink based model has been developed and the simulation results of the proposed model obtained by using MATLAB.***

***Key Words:*** *Smart Grid, SFCL, Fault current.*

## 1. INTRODUCTION

Numerical protection relay used for substation equipment protection, especially at the high voltage substation level, 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 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 which is cleaner, reliable, resilient and responsive than conventional power system. One of the key elements of the smart grid is decentralization of the power grid network into smaller grids, which are known as micro grids, having distributed generation sources (DG) connected with them. These micro grids may or may not be connected with conventional power grid, but the need to integrate. Various kinds of DGs and loads with safety should be satisfied. However, newly emerging problems due to these integrations are also of severe nature and needs to be taken care of. Two major challenges expected by direct connection of DGs with the power grid are the excessive increase in fault current and the islanding issue which is caused when, despite a fault in the power grid, DG keeps on providing power to fault-state network. Up to now, there were some research activities discussing the fault current issues of smart grid. But the applicability of a SFCL into micro grid was not found yet. Hence, solving the problem of increasing fault current in micro grids by using SFCL technology is the main concern of this work. The effect of SFCL and its position was investigated considering a wind farm integrated with a distribution grid model as one of typical configurations of the smart grid. The impacts of SFCL on the wind farm and the strategic location of SFCL in a micro grid which limits fault current from all power sources and has no negative effect on the integrated wind farm was suggested. Fault currents due to short circuit conditions that can develop from lightning strikes and other contingencies in electric power systems continue to increase due to growin g power demands, the introduction of distributed generation (DG) systems and changes to electric power systems due to the continued deregulation of electricity markets. An increase in the fault current of an electric power system leads to an increase in the complexity of its design. In order to reduce the mechanical and thermal damage to power system apparatus that can be caused when these currents exceed the protective capabilities of the switchgear equipment installed in the system and help ease restrictions placed on the design and operation of power systems, various types of superconducting fault currents limiters (SFCLs) are being actively researched.

### 1.1 Scope of work

The SFCL is expected to be an important part of future electric power systems, particularly in developing countrie s, where superconducting technologies are expected to make the largest impact and assist in providing safe, reliable and efficient power to those living in less affluent conditions. There is also a recent emphasis on smarter and more efficient use of power due to problems associated with global warming and diminishing fossil fuel reserves, for which superconducting technologies can provide a feasible solution. Loss of electrical energy due to resistance to current flow in traditional systems translates into wasted energy and waste economic resources, and currently approximately 10% of produced electrical energy is lost in the transmission and distribution system, which translates to an enormous amount. Superconductivity offers zero (DC) and near zero (AC) resistance to electrical flow; thus, the use of superconducting materials can improve overall electrical system efficiency while significantly reducing the size and weight of power components and machinery.

## 2. SERIES RESISTIVE SFCL

In a resistive FCL, the current passes through the superconductor and when a high fault current begins, the superconductor quenches: it becomes a normal conductor and the resistance rises sharply and quickly. This extra resistance in the system reduces the fault current from what it would otherwise be (the prospective fault current). A resistive FCL can be either DC or AC. If it is AC, then there will be steady power dissipation from AC losses (superconducting hysteresis losses) which must be removed by the cryogenic system. An AC FCL is usually made from wire wound non-inductively; otherwise the inductance of the device would create an extra constant power loss on the system. Grid ON Ltd has developed the first commercial inductive FCL for distribution & transmission networks. Using a unique and proprietary concept of magnetic-flux alteration - requiring no superconducting or cryogenic components the self-triggered FCL instantaneously increases its impedance tenfold upon fault condition. It limits the fault current for its entire duration and recovers to its normal condition immediately thereafter, as per reported series resistive SFCL Sung [1].

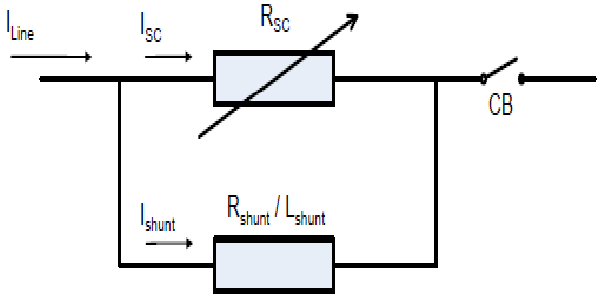



**Fig -1:** Resistive type SFCL

### 2.1 Inductive shielded SFCL

The limiter uses a superconductor to shield the magnetic field generated. The design is based on using a superconductive cylinder to shield the iron core from the AC magnetic field generated by the primary winding. During a fault caused, the magnetic field penetrates the superconducting shield at a large impedance .In this work we examined the magnetic field shielding of two oxide superconductive cylinders. We produced two magnetic shielding type SCFCLs with a control ring, and observed operating behavior of the fault current limiters

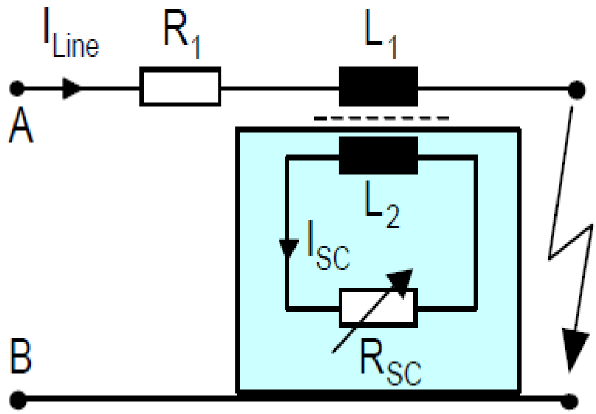



**Fig -2:** Inductive shielded SFCL

## 3. SIMULATION SET UP

The proposed system consists of a smart grid system in which generation, transmission, and distribution with an integrated wind farm as per K. Makki [2] shown in figure 3. As per L. Dessaint this model is designed and implemented by Matlab simulink [3].

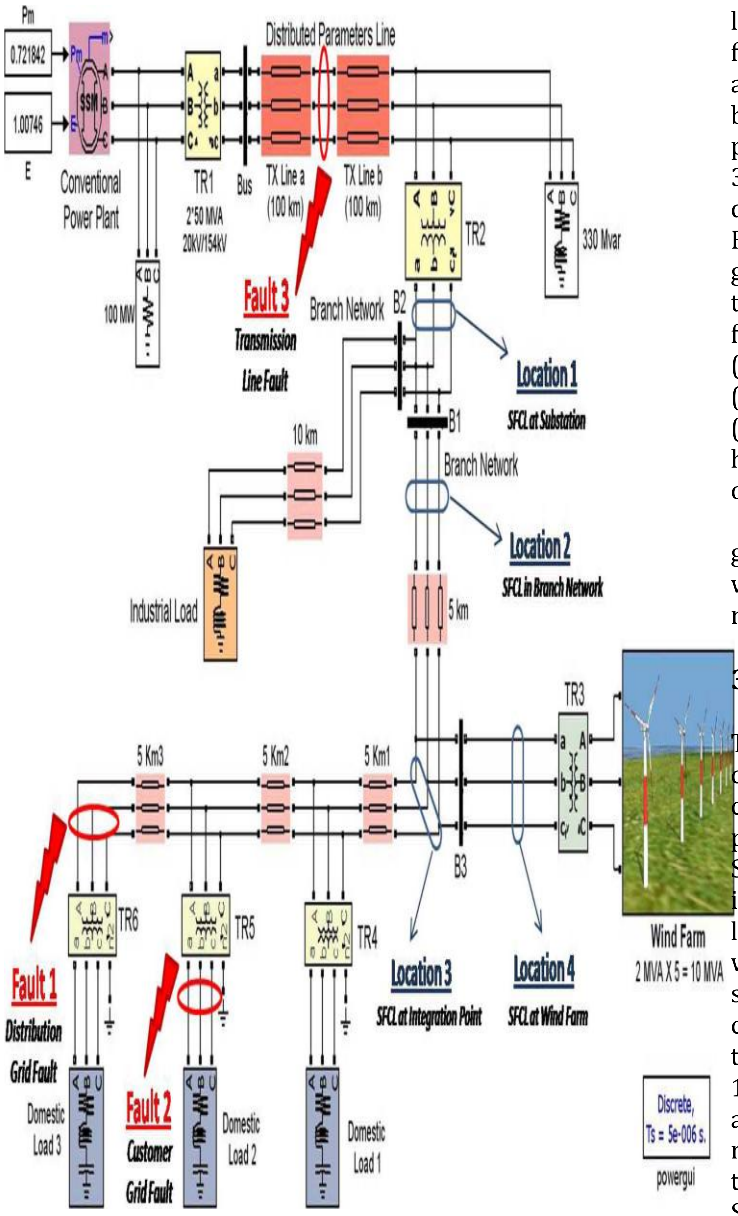



**Fig -3:** Proposed Smart grid System Model

A micro grid model was designed by integrating a 10 MVA wind farm with the distribution network. The power system is consisting of a 100 MVA conventional power plant, composed of 3-phase synchronous machine, and connected with 200 km long 154 kV distributed-parameters transmission line through a step-up transformer TR1. At the substation (TR2), voltage is stepped down to 22.9 kV from 154 kV. Here the industrial load (6 MW) and domestic loads (1 MW each) are being supplied by separate distribution branch networks in connected system The wind farm of 10 MVA connected with system in synchronized condition and it is directly connected with the branch network (B1) through transformer TR3 and is providing power to the domestic loads 1, 2 and 3. The 10 MVA wind farm is composed of five fixed-speed induction-type wind turbines each having a rating of 2MVA. At the time of fault, the domestic load is being provided with 3 MVA power out of which 2.7 MVA power is being provided by the 10 MVA wind farm. In Fig. 3 artificial fault and locations of SFCL are indicated in the diagram. Three kinds of fault points are marked as Fault 1, Fault 2 and Fault 3, which represent three-phase-to-ground faults in distribution grid, customer grid and transmission line respectively. Four prospective locations for SFCL installation are marked as Location 1 (Substation), Location 2 (Branch Network), and Location 3 (Wind farm integration). The output current of wind farm (the output of TR3 in Fig.3) for various SFCL locations have been measured and analyzed in determining the optimum location of SFCL in microgrid.

The exact location of SFCL where it get installed in smart grid system can only prevent and reduce the fault current within limit if it will increase beyond the expected value in magnitude of fault current during fault will arise.

### 3.1 Operation

The SFCL model works as follows. 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, SFCL's 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 three phase resistive type SFCL was modeled considering four fundamental parameters of a resistive type SFCL. These parameters and their selected values are: 1) transition or response time, 2) minimum impedance and maximum impedance, 3) triggering current and 4) recovery time. Its working voltage is 22.9 kV. Fig. 4 shows the SFCL model developed in Simulink/Sim- Power System. The SFCL model works as follows. 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, SFCL's 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, as per S. Sugimoto [4].

It has been located at substation (Location 1) and for a distribution grid fault (Fault 1), various SFCL impedance values versus its fault current reduction operation has been plotted. Maximum fault current (No SFCL case) is 7500 A at 22.9 kV for this arrangement.

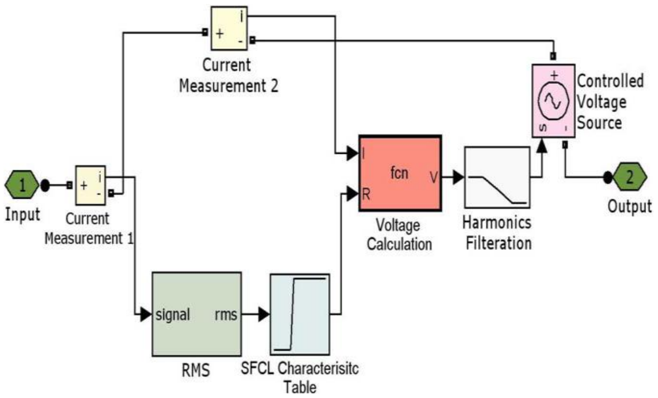
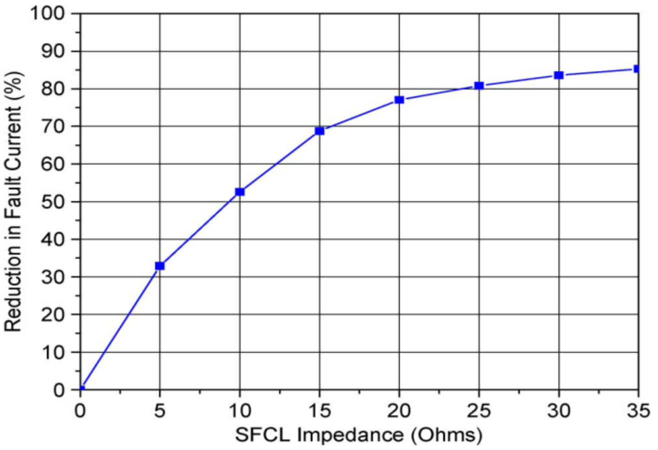



**Fig -4:** Single phase SFCL model in Matlab Simulink




**Graph -1:** SFCL performance evaluation graph indicating the relationship between SFCL impedance and reduction in fault current.

## 4. ANALYSIS AND RESULT

Four possible location of SFCL are analyzed for three different fault current as shown in Fig-3. First location available in substation where single SFCL is located. Second, single SFCL was located at Location 2 (Branch Network). Third, single SFCL was located at Location 3 (Wind farm integration point with the grid). Finally, in order to clarify the usefulness of dual SFCL installed together for different locations, SFCLs were located at Location 1 (Substation) and Location 4 (Wind Farm) respectively. The study at different location of SFCL is analyzed as per J. driesen [5].

### 4.1 Fault 1 at Distribution Grid.

In the case of SFCL located at Location 1 (Substation) or Location 2 (Branch Network), fault current contribution from the wind farm was increased and the magnitude of fault current is higher than 'No FCL' situation. These critical observations imply that the installation of SFCL in Location 1 and Location 2, instead of reducing, has increased the DG fault current. This sudden increase of fault current from the wind farm is caused by the abrupt change of power system's impedance. The SFCL at these locations (Location 1 or Location 2) entered into current limiting mode and reduced fault current coming from the conventional power plant due to rapid increase in its resistance. Therefore, wind farm which is the other power source and also closer to the Fault 1 is now forced to supply larger fault current to fault point (Fault 1). In the case when SFCL is installed at the integration point of wind farm with the grid, marked as Location 3 in Fig. 3.

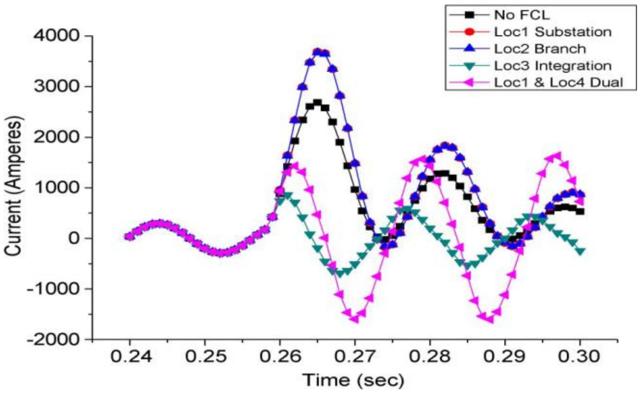



**Fig -5:** Comparison of the wind farm fault currents for four SFCL locations in case of fault in distribution grid (fault 1)

The wind farm fault current has been successfully reduced. SFCL gives 68% reduction of fault current from wind farm and also reduce the fault current coming from conventional power plant because SFCL is located in the direct path of any fault current flowing towards Fault 1. With dual SFCL installed at Location 1 and Location 4, 45% reduction in fault current is also observed. However, even though two SFCLs were installed, wind farm fault current reduction is lower than what was achieved by the single SFCL installed at Location 3. From the simulation results, it was known that the installation of two SFCLs (Location 1 and Location 4) is economically and technically not feasible.

### 4.2 Fault 2 at Customer Grid.

Fig. 6 shows a comparison between fault current from the wind farm (measured at output of TR3 in Fig. 3) for different SFCL locations in the case when a three-phase-to-ground fault was initiated in the customer grid (Fault 2 in Fig. 3). Fault 2 is comparatively a small fault as it occurred in low voltage customer side distribution network. The results obtained as shown in figure 7. Magnitude of fault is small in case of fault occurred in customer grid. The analyzed result of fault current of wind farm 10MVA for four location of superconducting fault current in case of fault occurred in customer grid is as shown in figure 7. The change in line impedance, magnitude of fault current arises is not much adequate but it sure to affect the wind farm and also other distributed generating sources nearby its premises.

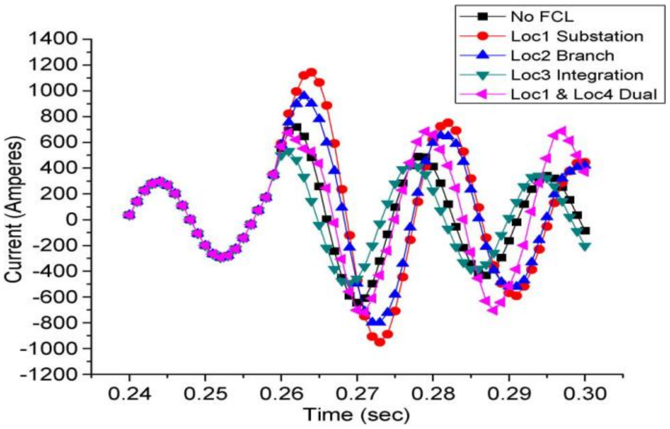



**Fig -6:** Comparison of the wind farm fault currents for four SFCL locations in case of fault in customer grid (fault 2).

### 4.3 Fault 3 in Transmission line

The rarely occurring transmission line fault which results in very large fault currents. Fig. 7 shows a comparison between fault current from the wind farm (measured at output of TR3 in Fig. 3 for different SFCL locations in the case when a three-phase-to-ground fault was initiated in the transmission line (Fault 3 in Fig. 3).

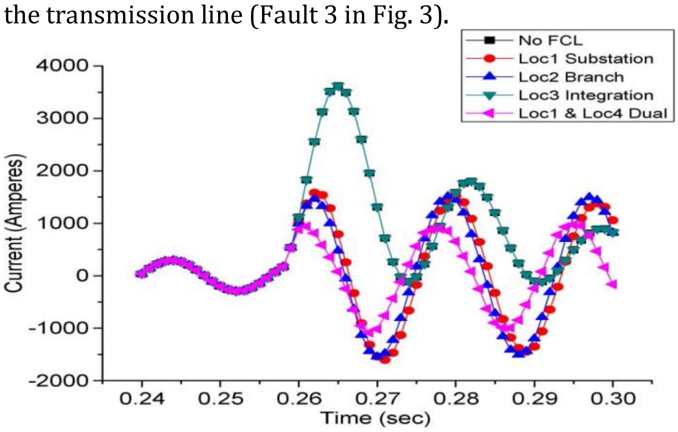



**Fig -7:** Comparison of the wind farm fault currents for four SFCL locations in case of fault in transmission line (fault 3) are similar to what were observed in the case of distribution grid (fault 1). Once again the best results are obtained when a single SFCL is located at location 3, which is the integration point of the wind farm with the distribution grid.

When a fault in transmission line occurs, fault current from the conventional power plant as well as the wind farm would flow towards fault point. In case of wind farm, fault current would flow in reverse direction through the substation and into the transmission line to fault point. In case of wind farm, fault current would flow in reverse direction through the substation and into the transmission line to fault point. The wind farm fault current reduced by implementing SFCL at location 1 & location 2. The majority of faults in a power system might occur in the distribution grid and the SFCL designed to protect micro-grid should not be expected to cater for the transmission line faults (Fault 3). An important aspect to be noted here is that wind farms on distribution side can contribute fault currents to transmission line faults and this phenomenon must be considered while designing the protection schemes for the smart grid. Fig. 8 shows the comparison between four SFCL installation scenarios and their contribution in wind farm fault current reduction for distribution grid faults (Fault 1 and Fault 2). When the SFCL was strategically located at the point of integration of the wind farm with the grid (Location 3), the highest fault current reduction was achieved. The performance of SFCL at this location was even better than dual SFCL located at Location 1 and Location 4 in micro grid.

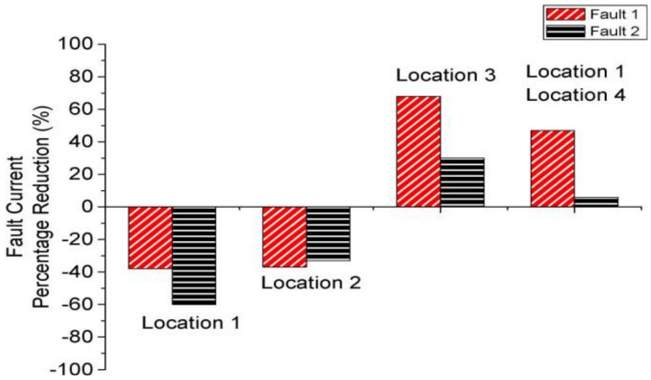



**Fig -8:** Comparison of the reduction in wind farm fault current for four SFCL installation scenarios.

Thus, power system safe and reliable operation as per reported by W. friedl [6]. Multiple SFCLs in a micro grid are not only costly but also less efficient than strategically located single SFCL. Moreover, at Location 3, fault current coming from the conventional power plant was also successfully limited.

**Table -1:** Reduction in wind farm fault current for various SFCL locations were summarized

| | Fault 1 Distribution Grid | | Fault 2 Customer Grid | | Fault 3 Transmission Line | |
|---|---|---|---|---|---|---|
| SFCL LOCATION | % | Affect | % | Affect | % | Affect |
| Location 1 | 38 | Increased | 60 | Increased | 57 | Decreased |
| Location 2 | 37 | Increased | 33 | Increased | 60 | Decreased |
| Location 3 | 68 | Decreased | 38 | Decreased | 0 | - |
| Location 1 & Location 4 | 47 | Decreased | 6 | Decreased | 72 | Decreased |

## 5. CONCLUSIONS

This paper presented a feasibility analysis of positioning of the SFCL in rapidly changing modern power grid. A complete power system along with a micro grid (having a wind farm connected with the grid) was modeled and transient analysis for three-phase-to-ground faults at different locations of the grid were performed with SFCL installed at key locations of the grid. It has been observed that SFCL should not be installed directly at the substation or the branch network feeder. This placement of SFCL results in abnormal fault current contribution from the wind farm. Also multiple SFCLs in micro grid are inefficient both in performance and cost. The strategic location of SFCL in a power grid which limits all fault currents with prevention from blackout to the DG source in the power grid. The installation of two or more SFCL in smart grid system will become costly and inefficient. Therefore the point of integration of wind farm with system is the exact location of SFCL to install where it will prevent maximum amount of current will be drawn through wind farm during fault.

## REFERENCES

[1] B. C. Sung, D. K. Park, J. W. Park, and T. K. Ko, “Study on a series resistive SFCL to improve power system transient stability: Modeling, simulation and experimental verification,” IEEE Trans. Industrial Electron., vol. 56, no. 7, pp. 2412–2419, Jul. 2009.

[2] K. Maki, S. Repo, and P. Jarventausta, “Effect of wind power based distributed generation on protection of distribution network,” in IEEE Developments in Power System Protection, Dec. 2004, vol. 1, pp.327–330

[3] L. Dessaint, K. Al-Haddad, H. Le-Huy, G. Sybille, and P. Brunelle, “A power system tool based on simulink,” IEEE Trans. Industrial Electron., vol. 46, no. 6, pp. 1252–1254, Dec. 1999.

[4] S. Sugimoto, J. Kida, H. Arita, C. Fakui, and T. Yamagiwa, “Principle and characteristics of a fault current limiter with series compensation,” IEEE Trans. Power Delivery, vol. 11, no. 2, pp. 842–847, Apr. 1996.

[5] J. Driesen, P. Vermeyen, and R. Belmans, “Protection issues in microgrids with multiple distributed generation units,” in Power Conversion Conf., Nagoya, April 2007, pp. 646–653.

[6] W. Friedl, L. Fickert, E. Schmautzer, and C. Obkircher, “Safety and reliability for smart-, micro-, and islanded grids,” presented at the CIRED Seminar: Smart Grids for Distribution, Jun. 2008, Paper 107.

## BIOGRAPHIES

Aakash P Patil, Student ME (EPS) SSGBCOET, Bhusawal.

Ajit P. Chaudhary, BE, ME, Associate Professor & Head of Department in SSGBCOET, Bhusawal.

Gaurav P Tembhurnikar, BE, ME, Assistant Professor in SSGBCOET, Bhusawal.