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INDEX

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Research Paper Electronics

Reduction Of Fault Current Using SFCL At The Suitable Location In The Smartgrid

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ABSTRACT

The integration of distributed generation with the existing power grid is a new approach in the smart grid. But, excessive fault current is the serious problem by connecting DG's. In this work a resistive SFCL was implemented to limit the excessive fault current. The designed SFCL model could be easily utilized for determining an impedance level of SFCL according to the fault-current-limitation requirements of various kinds of the smart grid system. A Smart grid model is considered consisting generation, transmission and distribution network with 9MW wind farm connected to grid. Three phase and single phase faults have been simulated at distribution grid and the effect of SFCL and its location on the wind farm fault current was evaluated. Consequently, the optimum arrangement of the SFCL location in Smart Grid with renewable resources has been proposed.

Keywords : Fault current, Smart grid, Super conducting Fault Current Limiter, Wind Farm

Introduction

Conventional protection devices installed for protection of excessive fault current in electric power systems, 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

A Superconducting Fault current limiter (SFCL) is an electrical device which can reduce fault current level within first cycle of the fault current, results in improved transient stability of the power system carrying higher power with greater stability [1].

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.

Two major challenges expected by direct connection of DGs with the power grid are the excessive increase in fault current [2] and the islanding issue [3] which is caused when, despite a fault in the power grid, DG keeps on providing power to fault-state network. As a consequence, classical protection techniques may become inadequate.

Hence, solving the problem of increasing fault current in micro grids by using SFCL technology is the main concern of this work. In this paper, 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 [4].

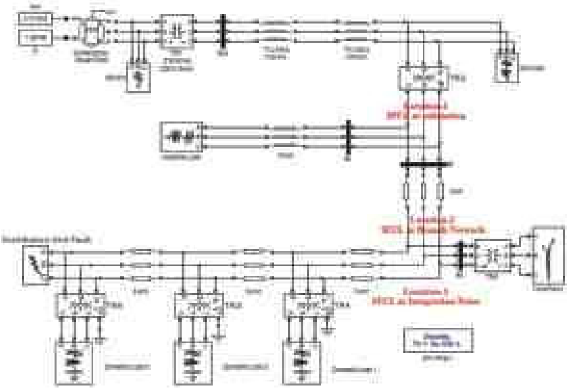
Simulation Set Up

Matlab/Simulink/simpowersystem was selected to design and implement the SFCL model.

A. Power System Model

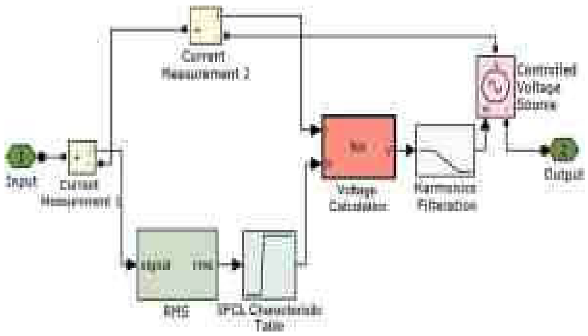
The power system is composed of a 100 MVA conventional power plant, composed of 3-phase synchronous machine, connected with 200 km long 154 kV distributed-parameters transmission line through a step-up transformer TR1. At the substation (TR2), voltage is stepped down to 22.9 kV from 154 kV. High power industrial load (6 MW) and low power domestic loads (1 MW each) are being supplied by separate distribution branch networks. The wind farm is directly connected with the branch network (B1) through transformer TR3 and is providing power to the domestic loads. 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 out of which 2.7 MVA is being provided by the wind farm.

Fig.1. Power system model designed in Simulink/SimPowerSystem. Fault and SFCL locations are indicated in the diagram.



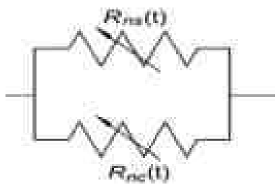
B. Resistive SFCL Model

Fig.2. Single phase SFCL model developed in Simulink/Simpowersystem



Operation of RSFCL

Fig.3. Structure of Resistive SFCL



When a fault occurs, the current increases and causes the superconductor to quench thereby increasing its resistance exponentially.

The values of Rnc(t) and Rns(t) of the SFCL are normally zero in a normal condition. They become non-zero time varying parameters during a fault depending on its unique characteristics. This behavior is called "quenching".

The associated equation for R_{SFCL} is expressed by [1],

$$R_{SFCL}(t) = R_m\,(1-\exp(-t/T_{sc}) \qquad (1)$$

R_m is the maximum resistance of the SFCL in the quenching state.

T_{sc} is the time constant of the SFCL during transition from the superconducting state to the normal state.

If a three phase fault (or any other grounding faults) with the fault resistance of R_f is applied, SFCL operates with a certain resistive value of RSFCL.The three phase resistive type SFCL was modeled considering four fundamental parameters of a resistive type SFCL. The parameters are: 1) Transition or Response time = [0.1 0.15] 2) Minimum impedance = 0.01 ohms and maximum impedance = 20 ohms 3) Triggering current = 1300 A. Its working voltage is 22.9 kV.

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.

Results And Discussion

Fig.-4. Comparison of the wind farm fault currents for distribution grid fault
(3-phase fault) (X-axis-time (sec), Y-axis-Current (KA)
(a) Without fault (10 KA) (b) With fault (19 KA)
(c) For SFCL at location 1&2 (25 KA)
(D) For SFCL at integration point (8 KA)

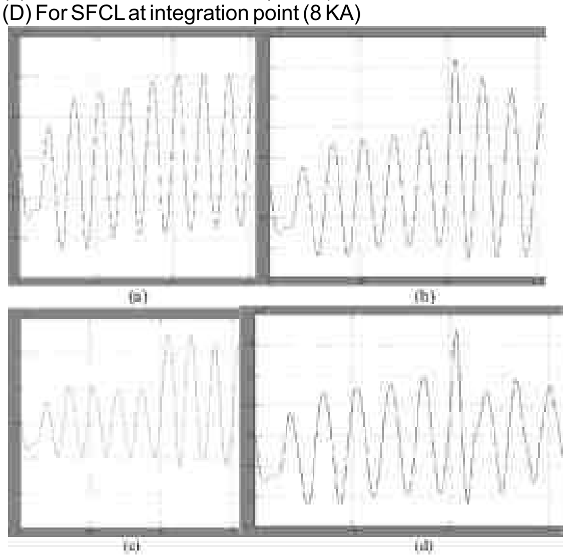
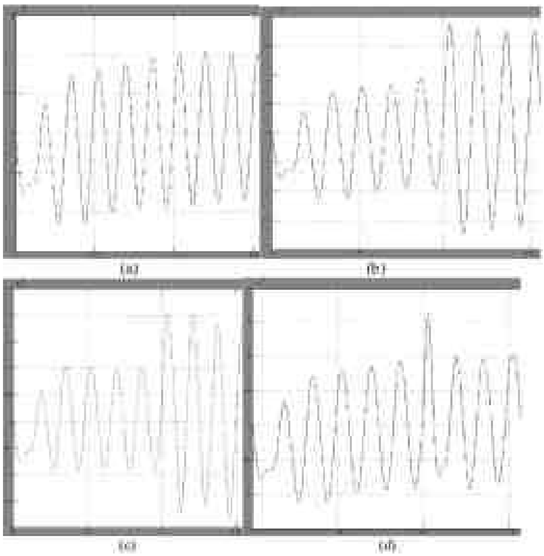


Fig.-5. Comparison of the wind farm fault current for distribution grid fault
(Single line to ground fault) (X-axis-time (sec), Y-axis-Current (KA))
(a) Without fault (10 KA)
(b) With fault (16 KA)
(c) For SFCL at location 1&2(20 KA)
(D) For SFCL at integration point (10 KA)



For distribution grid fault (both 3- phase to ground fault and L-G fault):

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 is now forced to supply larger fault current to fault point.

In the case when SFCL is installed at the integration point of wind farm with the grid, marked as Location 3 wind farm fault current has been successfully reduced. This reduction includes fault current from wind farm and also reduces the fault current coming from conventional power plant because SFCL is located in the direct path of any fault current flowing towards Fault.

Conclusion

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.

The strategic location of SFCL in a power grid which limits all fault currents and has no negative effect on the DG source is the point of integration of the wind farm with the power grid.

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