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Transformer Type Superconducting Fault Current Limiters for Further Developments in Smart Grid

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Abstract: ***Continuous increase in electrical power demand has leading to an increase in power grid size. The Distribution Generation is used to supply extra power to the grid but it increases the abnormal operation and fault current in the grid. this fault current level may cross the rated value of conventional circuit breakers and these circuit breakers allow to pass initial fault current cycles before getting activated in this case Superconducting fault current limiter can use successfully for reduce fault current including first cycles. As more reforms continue in the grid, it creates difference in fault current level. A Transformer type SFCL with Two Non-Isolated Secondary Windings is capable to change the limiting value of the fault current by changing of turns ratio between two windings in secondary side. Resistive type is the simplest form of SFCL having constant critical value. it possible to found feasible locations of these SFCLS in a power grid through a test. In this paper, Transformer Type SFCL placed instead of resistive SFCL in optimal positions to get advantages of both types of SFCLs motioned. This is done by using a power system model created by MATLAB/Simulink software. A wind farm as DG and artificial faults are included***.

Keywords: distributed generation (DG), Superconducting fault current limiter (SFCL), fault current, resistive type SFCL, Transformer type SFCL

1. Introduction

Distribution Generation is a Renewable Energy sources. It will be installed in the micro grid when more energy needed. Micro grids are the smallest networks decentralized from smart grid. DG installation in the micro grid can cause abnormal operation. This increases the level of the fault current in Micro grid. This fault current will cause to the abnormal operation of circuit breakers installed on the micro grid and it will allow to pass initial fault current cycles. To solve this problem, there are few methodologies are the upgrading of circuit, splitting existing substation bus and using of Series reactors and solid state fault current limiters etc. But these methodologies are causing economic and voltage loss. [1]. in these situations that the SFCL is most suitable for limit the fault current because of it has a zero electrical resistance at inactive state and a sudden reaction when fault occurs

After the fault, it automatically recovers its superconducting state with no disruptions on the supply. Transformer type SFCL is a advanced type inductive SFCL. it has two non-isolated secondary windings connected with super conductors. it can produce two quench events. Resistive is better when compared to Transformer but the main advantage of transformer typing is to change in the fault current limit by changing its turns ratio of its secondary windings [2]. SFCL has a critical value. It cannot change in resistive type SFCL. The value of current in a grid may change after a development but the critical current value of resistive SFCL is not change. By using transformer type SFCL it is easy to change current limiting value

The feasible location for Transformer type SFCL is finding by using a micro grid created by MATLAB software. Micro grid has a wind farm as DG and artificial faults for testing. The magnitude of current is different in different location so there is difference in fault current. So by placing SFCL in feasible location gives better result

2. Structure And Testing Of SFCLs

2.1 Resistive type SFCLs

Resistive type is the simplest form in SFCLs when this is not working, there will be zero resistance so it needs series connection .it dissipates low energy during normal current flow .when current increase than its critical value, resistance increase rapidly. Then the dissipated loss increases its temperature more than critical value. So it lost super conducting property and increase resistance. This state called as quench state. Because of the high resistance the fault current suddenly reduces [1].

The material called YBCO gives higher critical current value from a variety of super conducting material with respect to its radius. It also provides better mechanical stability. It is High temperature superconducting material usually cooled with liquid nitrogen to maintain its superconductivity

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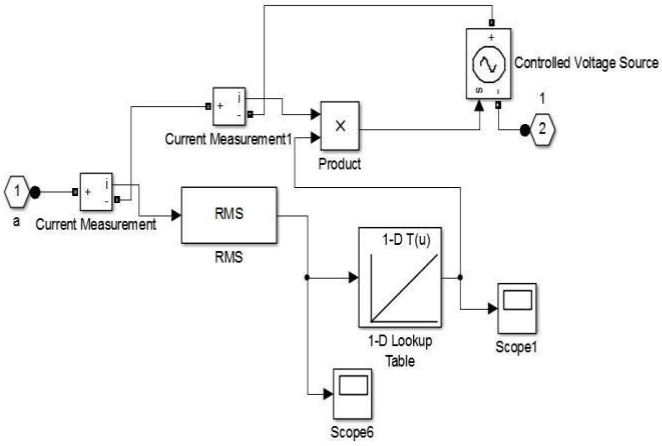

Figure 1: SFCL model created by MATLAB software.

The advantages of the Resistive SFCL are described as follows

1) SFCL can typically limit the first peak of fault current,
2) Faster than a circuit breaker.
3) The damage is reduced when it goes wrong
4) less expensive, smaller, and lighter
5) Resistive SFCLs limit the AC and DC components of the fault current
6) This improves the security of supply

2.2 Transformer type SFCL

Transformer type SFCL has two secondary windings. These windings are non isolated and connected with superconducting materials. Transformer type SFCL is an inductive type. it create two quench events. The super conducting material 1 and 2 connected to the first and second secondary windings of the transformer respectively as shown in the Fig. 2. The polarity of secondary windings can be creating as additive polarity or subtractive polarity. In additive polarity winding the voltage of the second secondary winding is in the opposite direction of first secondary winding and quench occurs after two or three cycles since the fault starts. In the case of a subtractive polarity winding, the voltage created at superconducting element 2 is equal direction to the voltage created at superconducting element 1.Then quench occurs at superconducting element 1 and 2 respectively. Unlike the additive polarity winding it reduce fault current in the early stage of a fault occurrence by full quench in two super conducting elements simultaneously so additive polarity winding is used in transformer type SFCL [2].

Inductive SFCL have more loss compared to resistive type SFCLS because Of the windings and core but the main advantages of inductive type SFCL Since the superconductor does not direct connection to line, normally heat loss is less. So Minimal cooling is required

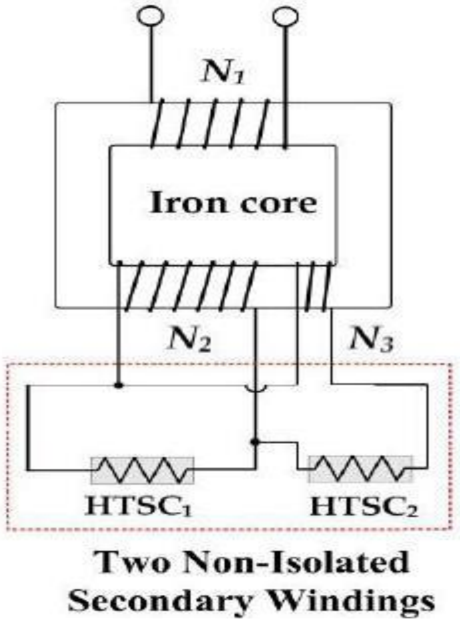

Figure 2: Transformer type SFCL with two non-isolated secondary windings

2.3 Testing of SFCLs

By testing SFCLs gives the current limiting properties during fault condition .the both circuits shown in the fig 3 have same source, load, and current measurement. In the first circuit Line A is faulted, line B is normal and line C is faulted with a resistive type SFCL. This circuit gives the output of resistive type SFCL when fault creates. The current waveforms in line A,B and C are colored as red , black and blue respectively in the output. In the second circuit have three faulted lines with transformer type SFCL with two non isolated secondary windings but different turns ratio in secondary winding. The current waveforms in line A,B and C in this circuit are colored as red, black and blue respectively in the output .This circuit shows how the fault current limiting values change by tap changing. Transformer used in this work has 60 turns in primary and 45+15 turns in secondary winding

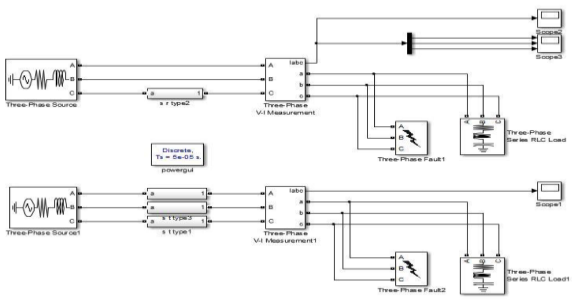

Figure 3: Test circuit built up in Simulink/SimPowerSystem

The outputs from these testing circuits shown in Figure 4 and 5.it gives resistive type SFCL can work with a fixed current limiting value and transformer type SFCL can change its current limiting value by tap changing

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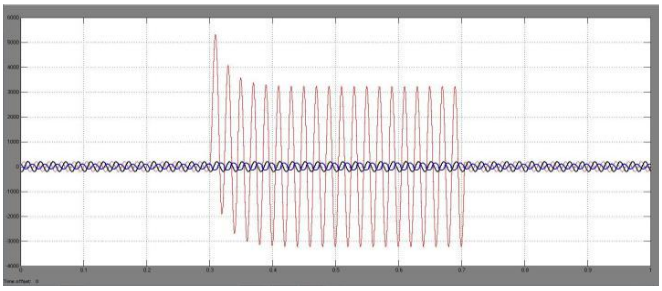

Figure 4: Output of resistive SFCL test circuit

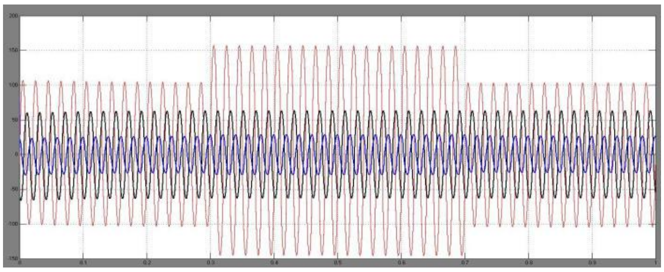

Figure 5: Output of transformer type SFCL with different tap position

3. Simulation Setup

The Fig.6 shows A smart micro grid created in MATLAB/ Simulink software. In this power network includes generating station, substation, integrated wind farm model, transmission system, and distribution networks with different loads. the MATLAB simulated systems have open architecture. It allow versatile analysis and graphics tools. The modeled power system was based on Korean electric transmission and distribution power system and as a distribution network wind farm of power 10MVA is used. It has five units of induction generator. Each unit of induction generator gives 2 MVA. A 100 MVA, 20KV, 50 Hz 3-phase synchronous machine act as a conventional power plant at starting of grid and connected to a step-up transformer of rating 20/154.this transformer connected to the substation through 200 km long transmission line. At the substation a transformer is stepped down voltage to 22.9 kV. There are domestic loads of 1MW in three sections and other is power industrial loads of 6MW. These loads directly connected to the substation. Low power loads are the domestic lodes they are equally placed by 5 km distance. The wind farm is supplying to 400V to the consumers, using 22.9KV/400V transformer. An artificial fault located at one of the domestic load as shown in Fig.6. During fault, wind farm power provided to the domestic loads in distribution network. For the testing of possible position in grid we need artificial faults in grid .for that, first fault locate on the distribution line, second fault located in consumer grid and the third on the transmission line [3]. In Fig.6 four locations 1, 2,3and 1& 4 are taken for a transient analysis to find optimum position to place SFCLs. By conducting a transient analysis with and without SFCL for each fault position, we get percentage reduction in fault current by SFCL at these locations as shown in table 1. From these values SFCL location 1& 4 is capable to reduce fault currents in the three positions and it can also make changes in percentage reduction of fault current. So we can take location 1& 4 as optimum position for transformer type SFCL to get protection with control of fault current limiting value. The power system model after placing transformer type SFCL in location 1& 4 is shown in Fig.6

Table 1: Percentage reduction in fault current

	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	30%	Decreased	0%	-
Location1 and Location 4	47%	Decreased	6%	Decreased	72%	Decreased

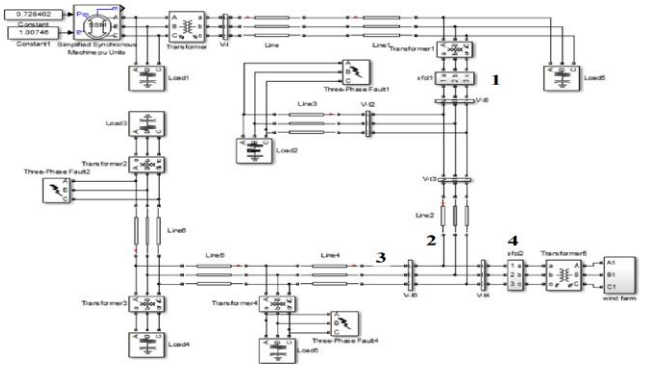

Figure 6: Modified MATLAB model of power system

3. Result and Discussion

After placing resistive type SFCL in the grid we need to check different in fault current for three fault positions of artificial fault created and control in fault current limiting values by tap changing. Here The red, violet and blue color waveform forms indicates the current through transmission lines, distribution & consumer grid respectively. The figure 7 and 8 gives the fault currents without SFCL

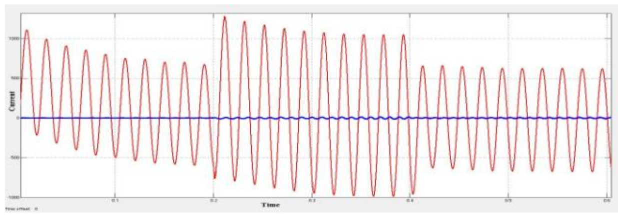

Figure 7: fault currents in transmission grid without SFCL

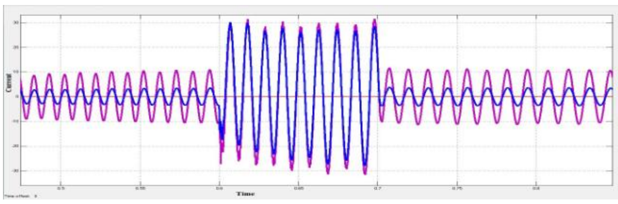

Figure 8: fault currents in distribution & consumer grid without SFCL

The fault currents with transformer type SFCL are shown in figure 9 and 10.from these it is clear that the fault current level control and mitigation using Transformer type SFCL is effective in location 1&4

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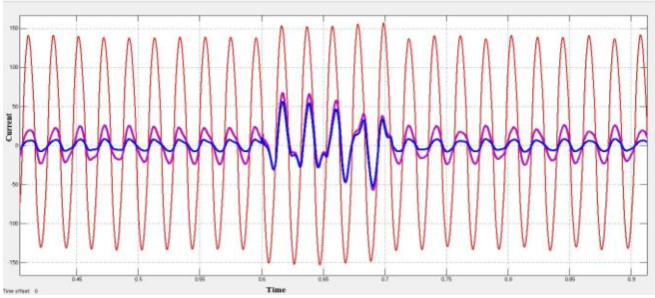

Figure 9: currents when taps in transformer type SFCL at first position

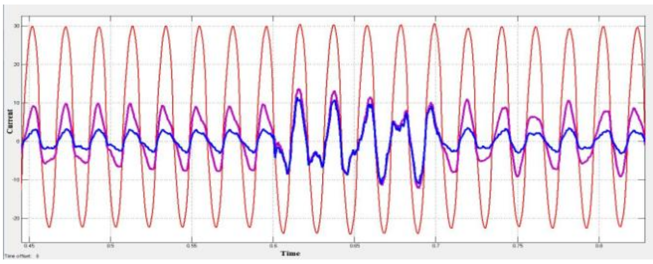

Figure 10: currents when taps in transformer type SFCL at last position

This transformer type SFCL with its taps in first position in location 1& 4 gives 150 A after limiting fault current and 30 A in its last tap position. It means the transformer type SFCL in location 1& 4 is suitable for overall protection from fault current created from developing smart grid without replacement in circuit breakers.

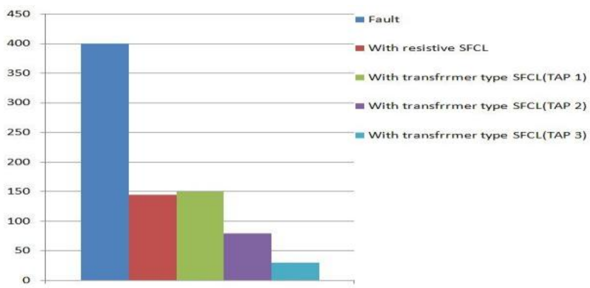

Figure 11: comparison of Fault current levels in transmission line using transformer type SFCL

4. Conclusion

The optimum positions are located using a transient analysis with and without resistive SFCL and tabulate the Percentage reduction in fault current. We can improve Percentage reduction in fault current using Transformer type SFCL with two non-isolated secondary windings. The fault current limiting characteristics of transformer type SFCL is shown in figure 11. Then Location 1 & 4 has taken as optimum locations for transformer type SFCL according to the table. The Transformer type SFCL with two non-isolated secondary windings easily adjusts fault current limiting value in the grid. No need to replace circuit breakers during increase in grid current. Transformer type SFCLs in optimum location will give overall protection from fault current created from developing smart grids

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