

Fuzzy Based Active SFCL to Reduce Fault Current in Distribution System

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ABSTRACT

In the modern power system, as the utilization of electric power is very wide, there is a frequent occurring of any fault or disturbance in power system. It causes a high short circuit current. Due to this fault, high currents occurs results to large mechanical forces, these forces cause overheating of the equipment. If the large size equipment are used in power system then they need a large protection scheme for severe fault conditions. Generally, the maintenance of electrical power system reliability is more important. But the elimination of fault is not possible in power systems. So the only alternate solution is to minimize the fault currents. For this the Super Conducting Fault Current Limiter using fuzzy logic technique is the best electric equipment which is used for reducing the severe fault current levels. In this paper, we simulated the unsymmetrical and symmetrical faults with fuzzy based superconducting fault current limiter. In our analysis it is proved that, fuzzy logic based super conducting fault current limiter reduces fault current quickly to a lower value.

Index Terms: *Distribution Generation (DG), Distribution System, Short-Circuit Current, SFCL, Fuzzy Logic.*

INTRODUCTION

In the present scenario, power quality and power supply are the main problems in power system. The distributed generation (DG) system has got lot of importance because of the limitation of conventional power generation [1]-[3]. The main advantage of DG system is

it reduces transmission cost. It has high quality and provides power to loads to maintain continuous supply.

Voltage sags and swells are also one of the most regular energy top quality disruptions in power systems. It is necessary to examine voltage sags and swells due to consumer's utilization of power at different times. Due to faults also the voltage sags and swells will occur. The presently used methods (FCL, SFCL) stop fault current at point of common coupling (PCC) after fault occurrence.

Due to high cost of superconductors this method is becoming uneconomical from the commercial perspective [4]-[7]. There by changing the superconductors with non- superconducting one is best solution to make it less expensive. It is worth noting that the disadvantage of non-superconductor is an electrical component reduction which is minimal in contrast with the complete energy. Whereas, SFCL is a device that detects and reduces the fault current in a network directly.

The paper provides the following contribution: The second part describes the working of active SFCL and discusses the usage of SFCL in to distribution system with distribution generation. The third part focus on photovoltaic array modelling and the forth part discusses SFCL based on fuzzy logic controller.

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SFCL IN DISTRIBUTION

A. Working of the SFCL:

From the following figure, SFCL consists of an air-core superconducting transformer and a voltage-type PWM converter. There are two superconducting self-inductance windings (L_{s1} , L_{s2}), and M_s is labelled as mutual inductance. Z_1 , Z_2 are circuit and fill impedances respectively. For filtering higher order harmonics L_d and C_d are used. Since the voltage-type converter's ability to managing energy return is applied by modulating the voltage of AC part, the converter is treated as regulated source U_p .

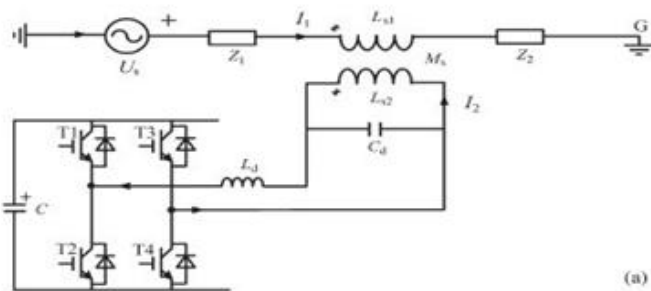


FIGURE 1: Single-Phase voltage compensation type SFCL

When there is no fault current, the impedance in SFCL is zero. So the dynamic SFCL will have no impact on the principle circuit, which means it operates without electric loss. When there is a fault current the impedance of SFCL is increased.

B. Usage of the SFCL in the system:

As appeared in following figure 2, when an L-G fault occurs in the feeder line 1 (phase A, k1 point), the SFCL is activated, and the fault current is promptly controlled. The circuit breaker reduces the fault current in 2-3 cycles, whereas SFCL takes half a cycle for limiting the fault current.

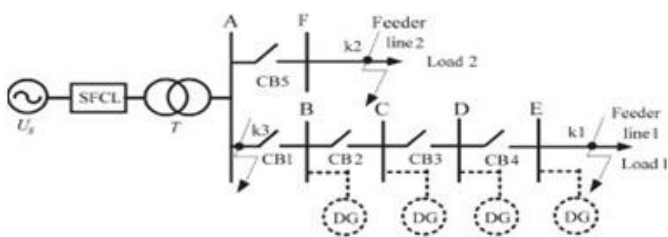


FIGURE 2: Application of SFCL in a System

PHOTOVOLTAIC ARRAY MODELLING

In this paper PV cell is used for distribution generation [8]. PV model is simulated by taking the effect of irradiance and temperature into consideration. In PV network of electrical phenomenon, cell is the necessary part. For the raise in appropriate current, high power and potential difference, the sunlight dependent cells and their region unit joined in short circuit current or parallel fashion called as PV exhibit are used. In practical applications, each and every cell is similar to diode with the intersection designed by the semiconductor material.

$$I = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I = I_{ph} - I_0 \left[e^{(qV_D/nkT)} \right] - (V_D/R_s) \quad (2)$$

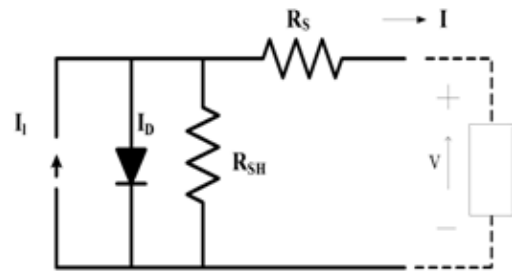


FIGURE 3: PV Electrical Equivalent circuit

Solar cell output power is given as the product of V and I.

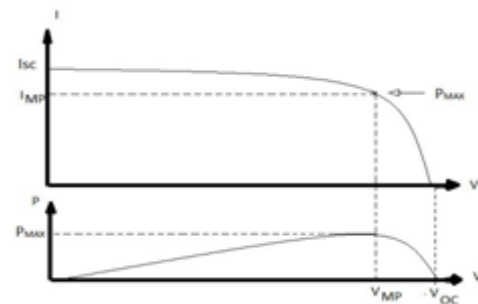


FIGURE 4: Response of output characteristics of PV Array

FUZZY LOGIC CONTROLLER

Fuzzy Logic Controller (FLC) is proposed for reduction of time for limiting fault current. Figure 5 shows the basic structure of Fuzzy Logic Controller [9]. Generally, the Fuzzy Logic Controller (FLC) is one of the most important software based technique in adaptive methods.

Analogizing with previous controllers, the FLC has low settling time and low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification

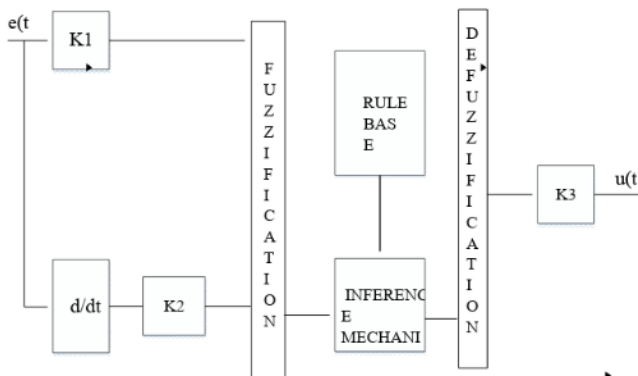


FIGURE 5: Basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type named triangular membership function [10] and method a used for defuzzification [11] is centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are indicated in terms of fuzzy set with the linguistic variables such as very low(vl), low(l), zero(z), high(h), very high(vh).

The linguistic variables are expressed using triangular membership functions in the mamdani type fuzzy inference system. In this paper, fuzzy inference system has two inputs and single output [12] are considered. The first input to fuzzy is error difference between voltage and the second input is chosen as rate of change of error of the first input. The number of linguistic variables for input and output is assumed as 5 categories in each case. Therefore, the numbers of rules are formed as 25. The fuzzy rules are obtained with 'if-then' statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND i.e., minimum.

Description of the power system:

SFCL

| | |
|------------------------------|------|
| Primary winding Inductance | 50mH |
| Secondary winding Inductance | 30mH |

Transformer

| | |
|----------------------------|-------------|
| Capacity of transformer | 5000kVA |
| Turns ratio of transformer | 35kV/10.5kV |

Line Details

| | |
|-----------------|--|
| Feeder Length | $L_{AF} = 5km, L_{AF} = 3km, L_{AF} = 3km,$ $L_{AF} = 9km, L_{AF} = 15km$ |
| Line Parameters | $(0.259+j0.093) \Omega/km$ |

Load Details

| | |
|--------------------------|-------------------|
| Impedance of First Load | 50 Ω |
| Impedance of Second Load | $(10+j12) \Omega$ |

MATLAB/SIMULINK RESULTS

The SFCL is introduced in the distribution system, and two PV units are incorporated into the framework, and one of the PV is introduced in the Bus B. For the other PV, it can be introduced in a desired position among the Buses C-E (named as PV2).

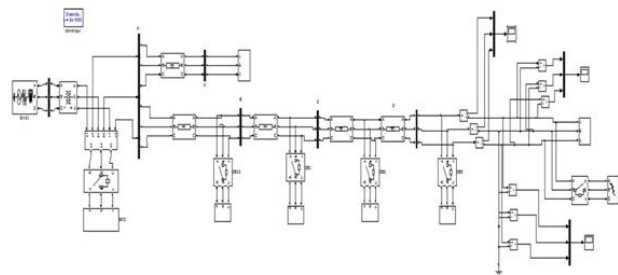


FIGURE 6: Simulation Diagram for the System

The following faults (LG, LLG and LLL) are simulated for the duration of 0.02s to 0.05s and the results are shown in the following curves. Green, pink and blue colors indicate A, B and C phases respectively.

Case 1: Single Line – Ground Fault

Case a: Without controller:

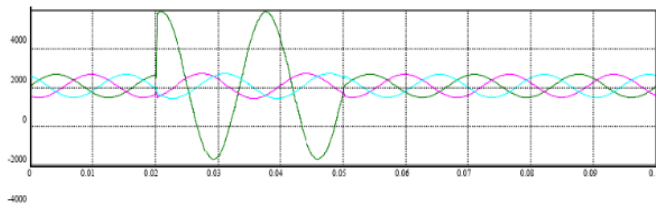


FIGURE 7: Current waveform under L-G fault condition

Case b: With SFCL

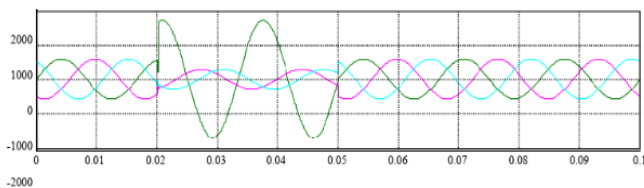


FIGURE 8: Simulation Result for Feeder Current under L-G Fault

Case c: With Fuzzy Controller

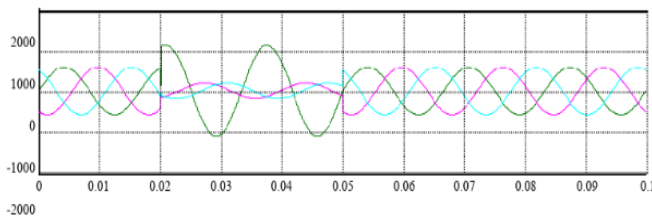


FIGURE 9: Simulation Result for Feeder Current under L-G Fault

Case 2: Double Line Fault

Case a: Without controllers:

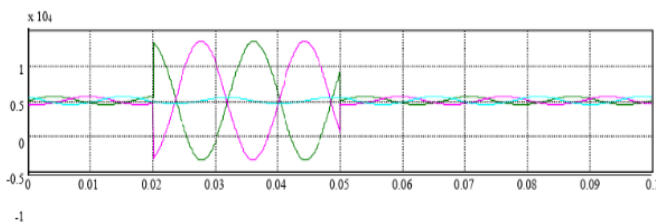


FIGURE 10: Current waveform under L-L fault condition

Case b: With SFCL:

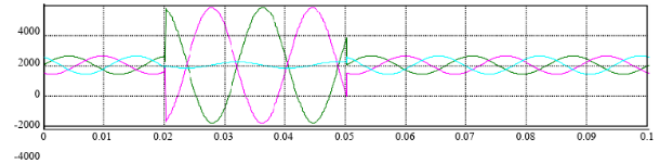


FIGURE 11: Simulation Result for Feeder Current under L-L Fault

Case c: With Fuzzy Controller

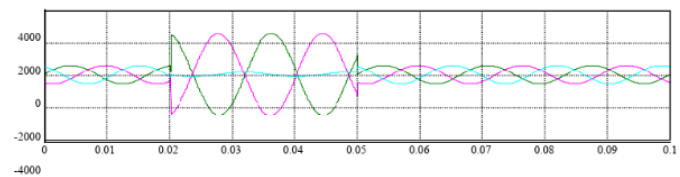


FIGURE 12: Simulation Result for Feeder Current under L-L Fault

Case 3: Double Line – Ground Fault Case a: Without controllers:

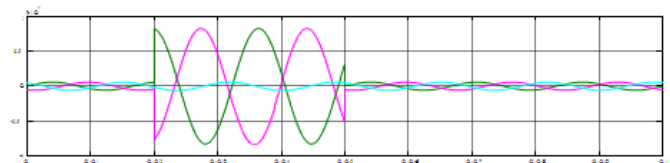


FIGURE 13: Current waveform under L-L-G fault condition

Case b: With SFCL:

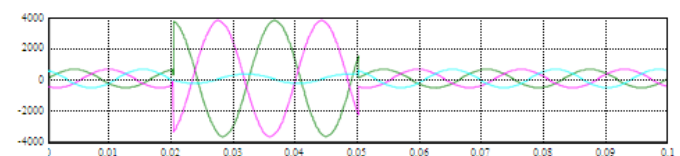


FIGURE 14: Simulation Result for Feeder Current under L-L-G Fault

Case c: With Fuzzy Controller

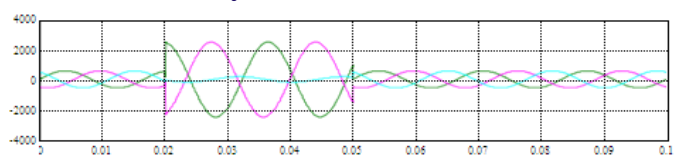


FIGURE 15: Simulation Result for Feeder Current under L-L-G Fault

Case 4: Three Phase Fault

Case a: Without controllers:

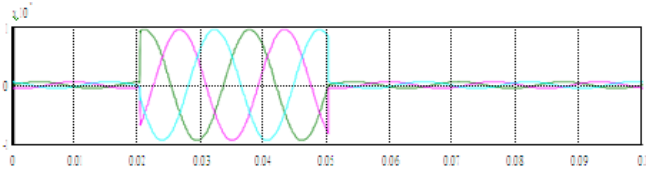


FIGURE 16: Current waveform under L-L-L fault condition.

Case b: With SFCL:

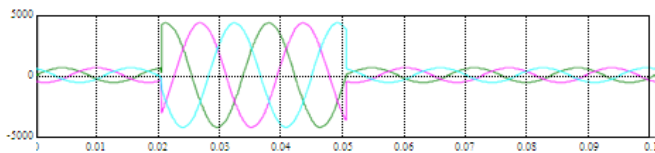


FIGURE 17: Simulation Result for Feeder Current under Three Phase Fault

Case c: With Fuzzy Controller

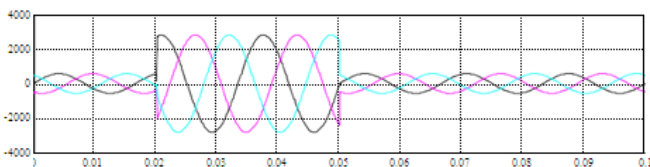


FIGURE 18: Simulation Result for Feeder Current under Three Phase Fault.

TABLE 1: Fault Currents for different faults for fault duration of 0.001s to 0.02s (1 cycle)

| Type of Controller ↓ | Type of Fault → | Line-Ground | Line-Line | Double line-Ground | Three phase |
|----------------------|-----------------|-------------|-----------|--------------------|-------------|
| Without Controller | | 3500 | 8100 | 8200 | 8980 |
| SFCL | | 1550 | 3650 | 3700 | 4040 |
| FUZZY | | 1050 | 2420 | 2480 | 2700 |

After observing the table 1 the following inference can be obtained. SFCL controller brings the fault currents to less than 50 % of the fault current without controller.

The fuzzy controller brings the fault current below 35% of the fault current without controller. Therefore Fuzzy controller is better than SFCL.

CONCLUSION

In this paper the faults on three phase power system is studied without controller, with SFCL controller and with Fuzzy controller. The single line to ground, line to line, double line to ground and three phase line faults are considered for all the above three cases. The fault current curves for all the cases are shown in Fig 9 to Fig 18. The results about fault currents are tabulated in table 1. The table 1 indicates that fuzzy controller is better than SFCL controller for all the faults.

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