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Protection of Energy Storage System in a Distribution System Using Fault Current Limiter

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ABST RACT:

In this project a fault current limiter is used for protection of Energy storage in a power distribution system for double L-G and triple L-G faults. Energy storage systems are crucial for power systems technologies. Though an Energy Storage System would not generate energy, its function is very crucial for the planning and operation of electrical power systems, principally for the maintainance of stable and reliable power quality in the distributed systems . More over an energy storage system is increasingly being used to supply excess or deficit power to the Grid in case of shortage of supply of power. So it is vital to keep an Energy Storage System interconnected with the Grid without interruption and to supply electrical power to the Grid. Here a fault current limiter is used to keep an Energy Storage System from disconnecting to the Grid in case of ground faults and it's effect is analyzed in different feeders for double L-G and triple L-G faults by MATLAB/SIMULINK model.

INTRODUCTION:

As there is a great demand for energy storage systems,these are interconnected to the grid in the form of distribution generation units for the maintainance of enough energy storage to maintain the stable and reliable power output . An Energy Storage System will store excess energy in excess of supply and delivers to loads when there is a deficit in supply[1].One of the main solution to solve the stability problems is to have abundant energy storage systems so that power system network will function in an effective manner without going into instability.Moreover these storage systems will maintain the quality of power by keeping constant power Energy storage systems are very important for power systems network.

Though Energy Storage Systems are not able to generate energy, its role is crucial for the planning and stable operation of an modern power system technologies, predominantly in order to maintain stable and reliable power output in the distribution generated systems.. Moreover, these systems are different in the costs and upgrades of the transmission and distribution capacity for the meeting of upgrowing power demand in the peak-hours . Moreover these energy storage systems have been developed to improve the capability of non conventional energy sources.In addition to that it provide additional or excess amount of reactive power depending upon loading conditions[5]-[7]

Although an energy storage system contributes several benefits for electrical power systems, they have some sort of drawback that is focused on the actual protection for a double and triple line-to-ground fault current a lot like some sort of Distributed generation[8]. To interconnect a generator to a power system and provide electrical isolation there are various kinds of connections to interconnect transformers. Meticulously, a grid-side grounded wye-delta connected transformer is most common in interconnection of all central generation station to the distributed generation systems[9]. The energy storage systems are interconnected with the power system in the correlation. The ground fault current trips a ground over current relay on a four wire, multigrounded neutral distribution systems[8] Moreover, it can disturb the coordinated power system protection and will eventually lead to the disconnection of the energy storage from the interconnection of grid.

The introduction of energy storage systems to distributed power units will lead to additional ground fault currents that will change the direction of fault current and coordinated relay protection. One of the most effective solutions to solve the problems in fault current is to have fault currnt limiters

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to protect energy storage systems to maintain stable operation of the distribution system , because of its fast fault current limiting action and its automatic recovery characteristics[2]. The consequence of a fault current limiter applied to an interconnection transformer with an Energy Storage System is realized. A resistive Fault Current Limiter and distributed generation system with energy storage has been modeled using the MATLAB/ SIMULINK [3]-[4] and is elaborated in Section II.The IIIrd section has analyzed the fault current limiter and it has not affected the protective relay between the distributed generation system and the energy storage system and the conclusions has been presented in the last section

II. MODELING OF FCL WITH AN ENERGY STORAGE SYSTEM:

Modeling of resistive FCL:

FCL is the utmost effective fault current limiters to prevent the raising of fault current from increasing in magnitude because of its fast current limiting capability.Although there are various types of FCL models, the resistive type FCL is preferred because of its simple principle and compact structure of small size[7]-[8]. In this project, a resistive fault current limiter has been modeled using mathematical equations.

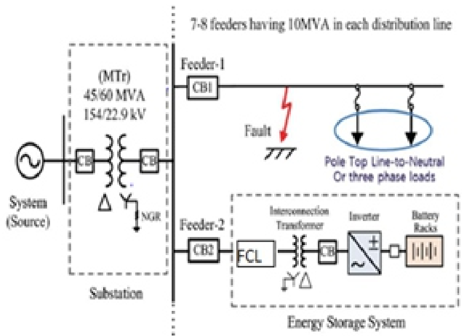

Fig1.FCL equivalent circuit.

SPECIFICATIONS OF THE POWER DISTRIBUTION SYSTEM WITH AN ESS

	Data
Source	154 kV, j1.75%
Main Transformer (MTr)	154/22.9 kV, 60 MVA, j15%, NGR: 5 %
Interconnecting Tr.	22.9/0.44 kV, 20 MVA, j6 %
Line Impedance (ACSR 160 mm^2)	$Z_1 = 3.86 + j7.42$ %/km $Z_0 = 9.87 + j22.6\ 8$ %/km
Feeder Length	Feeder-1: 10 km Feeder-2: 100 m
Fault Location	Feeder-1: 5 km from CB1
System Base	100 MVA, 22.9 kV

These were verified mathematically and are implemented using MATLAB/SIMULINK software.The resistive type fault current limiter as a function of time(t) is

given by: $RFCL(t)=Rn\_1-exp\_-(t-t0)TF\_\_ \quad t0 \le t < t1$, (1)

$RFCL(t)=a1(t-t1)+b1 \quad t1 \le t < t2$, (2)

$RFCL(t)=a2(t-t2)+b2 \quad t \ge t2$ (3)

where Rn and TF are the convergence resistance and time constant, respectively. t0, t1, and t2 indicate the start of quench time, primary stage of recovery, and secondary stage of recovery, respectively..A grid-scale ESS comprises of a battery bank,, power ac-dc power electronics interface converter, protective circuit, and a transformer to convert the output of the energy storage system to the transmission or distribution system voltage level[5].

The above figure shows an Energy Storage System with fault current limiter for simulation to analyze the effect of double LG and triple LG faults.the secondary of the transformer contains loads,and an interconnecting transformer,circuit breaker and relay.When there is any fault the circuit breakers will open the contacts and clears the fault with the relay operation[3] .

The feeders 1 and 2 are installed with the circuit breakers 1 and 2 to clear the fault under any short circuited conditions .. In order to incorporate the Energy Storage System, a grounded star (primary side)-delta (secondary side) connected transformer is used in the project and is shown in Fig. 1. The rated voltage levels, current and power levels are tabulated and analyzed.

III. FCL AND WITHOUT FCL UNDER DIFFERENT FAULTS :

To realize the effect of FCL on a double line-to-ground and triple line-to-ground fault in the distributed generation with an Energy Storage System, and the simulations were analyzed with and without the existence of an FCL and modeled using MATLAB/SIMULINK

A. Case 1: DOUBLE AND TRIPLE Grounded Fault without an FCL:

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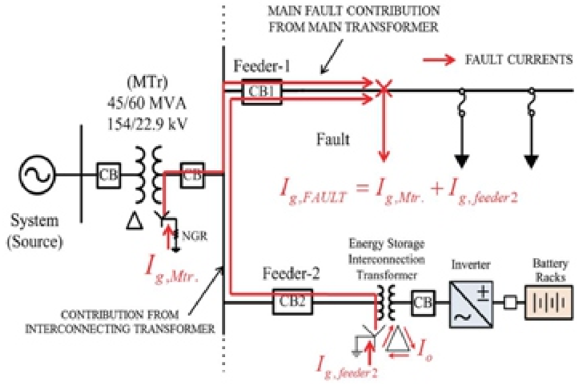


The performance of the Energy storage System interconnection transformer without FCL for double and triple line-to-ground fault is analyzed in this connection. Fig2 shows how the interconnection of ESS, which is not connected with FCL, contributes for a double and triple grounded fault in distribution system. The directions (Ig, Mtr. And Ig, feeder2) indicate the direction of the fault currents from the substation and transformer ground to the faulted point.The fault current flows back to the interconnected transformer and leads to the extra flow of current to the faulted point.The intensity of faulted current depends on the impedance as well as magnitude of the transformer

On the delta side of the interconnecting transformer,in order to balance the extra magnetic motive force no zero sequence currents will flow in the windings. The flow of fault current is through the ground of the transformer main connection and not through the ground of the interconnection transformer. Thus ESS will create a new path for zero sequence current The figure 2 shows the fault current or a zero-sequence feeder currents caused by the double and triple grounded fault in feeder-1 by not having an FCL connection to the ESS interconnection transformer. The double and triple grounded fault is simulated 0.15s in phase for feeder-1. The circuit breaker 1 and 2 are tripped with the effect of faulted current and the zero sequence current that is flowing through the interconnection transformer .

So the energy storage system is automatically disconnected from the network when a gronded fault current appears.. As a result ther is a increase of fault current in the second feeder drastically because of grounded fault. The reason for the increase of fault current in feeder2 is because of the zero sequence current that is flowing through each phase of the ground of interconnection transformer. Fig3 shows the interrelated phase and zero sequence currents.

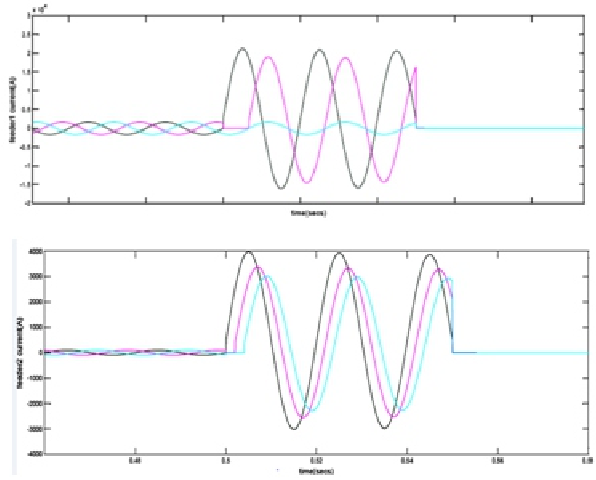


Fig2.(a)feeder currents caused by double l-g fault in feeder 1(b)feeder2 currents without FCL

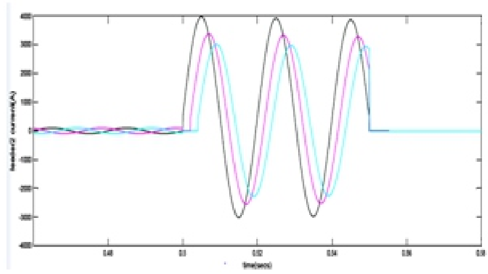


Fig3.(a)Feeder1 currents by triple L-G fault in feeder1 without FCL

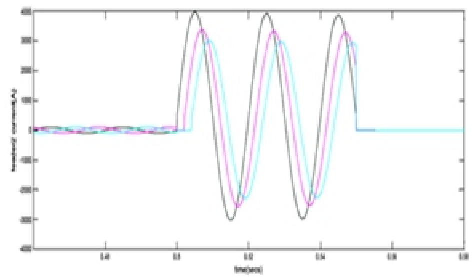
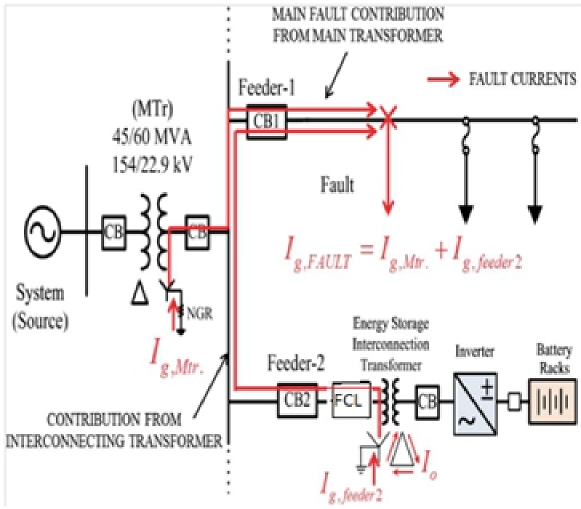


Fig3(b)feeder 2 currents by triple L-G fault in feeder 2 without FCL

Case 2: DOUBLE AND TRIPLE Grounded Fault With an FCL

The results for the ESS interconnection transformer along with FCL for a double and triple grounded fault is described in this case[6]-[8].. The arrows (Ig,Mtr. andIg,feeder2) indicate the fault current direction to the substation and to the ground of ESS interconnection transformer.. Despite a double and triple grounded fault, FCL does not allow to detach the Energy

Storage System from the power system, because of the zero-sequence currents flows through the ground of the transformer main conection in the substation due to the double and triple grounded fault, with the comparison of the effect of the presence of an FCL[5]-[9] As the FCL blocks the zero sequence current increases because the FCL will not allow the ground fault current to pass through the interconnection transformer. So the zero sequence current that is flowing through the ground of the interconnection transformer will decreased and thus ensure the continuity of power supply even though there is fault.[7]-[9].



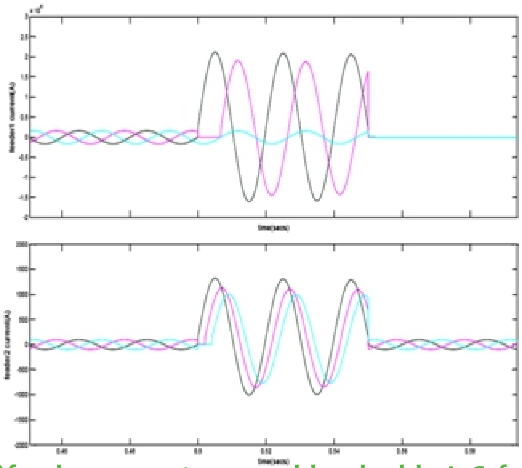
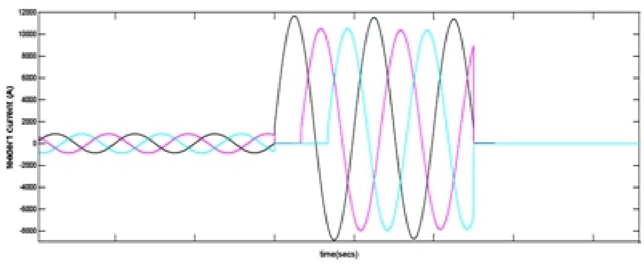


Fig4(a)feeder currents caused by double L-G fault in feeders1(b)in feeder 2



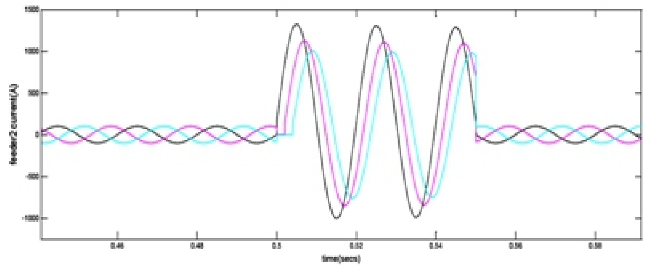


Fig5(a)feeder currents caused by triple L-G fault in feeder 1(b)in feeder 2

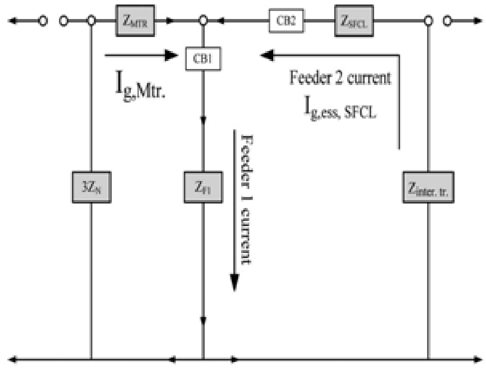


Fig6 zero sequence equivalent circuit

The above figure shows the equivalent circuit of the zero sequence currents and the flow of faulted currents under faulted conditions with an fault current limiter.

IV. CONCLUSION:

Now we have have concluded the fault current limiter and the energy storage system with the interconnection transformer has ensured the continuity of power supply even under faulted conditions.The FCL has created a new zero sequence current path for the faulted current that causes disturbances in the flow of faulted current.More over the fault current limiter application has also protected the power system network from sudden grounded faults.therefore the Fault current limiter has made the power system network to be stable and reliable by ensuring the continuity of power supply.Therefore we have concluded by the MATLAB/SIMULINK software the FCL has improved the power supply by comparison of the results with and without FCL application

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