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AC/DC Reactor Based Solid State Fault Current Limiter

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ABSTRACT

This paper proposes a novel AC/DC Reactor Based Solid State Fault Current Limiter Using PIC Microcontroller i.e. one series reactor which operates in ac and dc modes. In this proposed BSSFCL, it includes a rectifier bridge with a reactor. In normal operation mode this reactor is used as a dc reactor and as an ac reactor in fault conditions. Its negligible impedance in normal operation mode and its high impedance during a fault interval using simple and novel switching are the two advantages of the proposed BSSFCL over the existing dc reactor-type and AC reactor type FCLs. That is, in other words, during the normal operation mode, the proposed BSSFCL operates in dc mode and in the fault interval, its topology is changed to the ac mode. This switching decreases the switching transient recovery voltage and considerable impedance is introduce during the fault period. Software is used for simulations is MATLAB/Simulink

I. INTRODUCTION

Almost in every modern civilization field, there is the requirement of electrical energy which has resulted in a considerable increase of electrical power consumption. To reach the large electrical energy demand, the size of the power generating stations has become large. Now a days, in many cases, the generating stations are connected among themselves by interconnected networks (power grids) and makes the utility systems extremely large. Modern electrical power grids also have put forward to go for increased use of distributed generation (DG) which is placing smaller local generation sources closer to the loads.

Usually the consumption area of electrical power is very wide, the chances of any kind of accident, fault or abnormal condition is very common. In a power utility network, an short circuit is created by sudden accidents. The sudden reduction of the impedance of the power utility network during short circuit causes an increase in current, termed a fault current. It is a large fault current surging through the various parts of power grids and responsible for causing a voltage reduction too.

The increase of electric power consumption has necessitated an increase in the system fault current levels which has led to larger mechanical and thermal stresses and endanger the mechanical integrity of power system hardware viz. circuit breakers, transformers and other equipments. The increase in load, generation, interconnection and penetration of DG into power network rapidly increase the short circuit fault current level to or exceeds the capacity of protective switchgear such as circuit breaker. The short circuit fault current level in some places becomes so high that the breaking capacity of the circuit breaker reached to its maximum possible rating which is limited by the physics of the applied dielectric medium. Hence, the circuit breaker must either be upgraded or replaced in the near future. Neither up gradation nor replacement is economical and feasible from utilities perspective as the levels of fault currents would continue to grow with the increase in power demand.

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Because of these reasons the importance of limiting the fault current has been increased considerably. With the limited fault current, a breaker with a low rating or existing rating can be used and is cost effective compared to the breaker replacement.

Thus, it is required to find a more effective way to limit fault currents in power systems which fulfills the following criteria: the normal impedance of the system should not be increased, power supply availability should not be affected and the fault current should be limited to an acceptable value. Hence Fault Current Limiters (FCLs) are expected to provide the required protection for power systems from excessive short-circuit currents. A Fault Current Limiter can be defined as: "a device which entail negligible impedance in the line during normal operation of power system, but limits fault current to a predetermined level in case of a fault". Figure 1. shows typical waveforms of fault current with and without FCL.

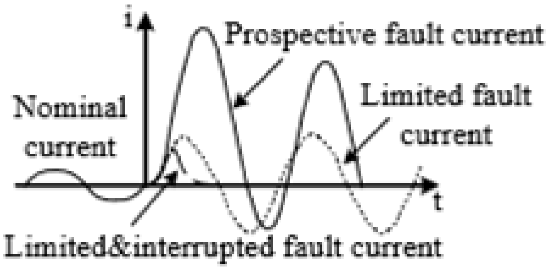

Fig:1- Waveforms of fault current with and without FCL

2.Traditional Devices For Fault Current Protection

The traditional devices which are used for fault current limitation,are:

- A fuse is a simple, cheap, rugged, small size and reliable protective device that can be used to interrupt fault currents as high as 200kA. A fuse is a self triggering device and requires neither sensors nor actuators. A fuse can open in less than half a cycle at current levels which are well under the peak available fault current. A major disadvantage of a fuse is being a single use device, which has to be manually replaced and causes prolonged service interruption;
- A Circuit Breaker (CB) can be “tripped” and reset either automatically or remotely. However, CBs with high current interrupting capabilities are bulky and expensive electro mechanical systems. CBs require maintenance and calibration and have a limited lifetime and number of cycles
- The high impedance transformer with their high losses makes the system inefficient and lowers voltage regulation.
- The air-core reactors are subject to large voltage drops, incur substantial power loss during normal operation and require installation of capacitors for volt-ampere reactive (VAR) compensation.
- The system reconfiguration using bus-splitting besides adding cost reduces the system reliability and its operational flexibility.

Now the Solution is either to upgrade the substation to cope with the new maximum short circuit current from mechanical and thermal point of view. This will require huge investment or, add a device which reduces the short circuit current to a value which our existing substations can easily handle.

Hence there have been an increase in the number of studies on the alternative solution to improve the reliability of electrical systems and one of them is the application of a fault current limiter (FCL).

The main purpose of the installation of FCL into the distribution system is to suppress the fault current. The

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FCL is series element which has very small impedance during a normal operation. If the fault occurs the FCL increases its impedance and so prevents over-current stress which results as damaging, degradation, mechanical forces, extra heating of electrical equipment.

II. What is FCL?

Fault Current Limiter is a device which has the potential to limit fault currents and to enhance system stability. Fault current limiters (FCL) reduce the fault current and make possible the use of lower rated protective devices A Fault Current Limiter (FCL) is a revolutionary power system device that addresses the problems due to increased fault current levels. As the name implies, a FCL is a device that mitigates prospective fault currents to a lower manageable level.

2.1 Role of fault current limiter

As mentioned earlier, the role of the FCL is to limit prospective fault current levels to a more manageable level

2.2 Proposed Confuguration

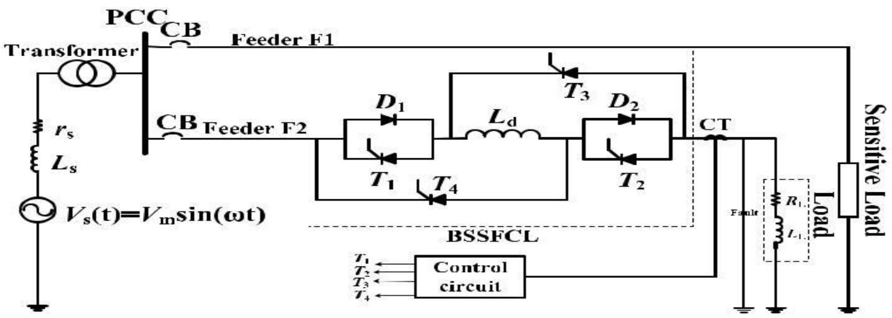

Fig:2 - Proposed BSSFCL configuration in two-feeders network

2.3 Operation Principle And Sequence Of Events

The basic idea of any bridge type fault current limiter, is as follows,

1) At $t < T_{fault}$, the impedance of the proposed FCL is close to 0Ω

2) At $t > T_{fault}$, the impedance of the proposed FCL rises sharply within a few milliseconds.

The fault current limiter (FCL) is the best solution for the fault current limitation Regarding FCLs protective reaction, they can be considered in two types. One type limits the fault current to an acceptable level, suitable to be safely interrupted by the circuit breaker (CB). The other type acts as a breaker and interrupts the fault current itself. In this paper, the first type, that is, non interrupting FCL, is investigated. Due to the type of the reactor, FCLs can be categorized in two types. One type employs the dc reactor and other one uses the ac reactor to limit the fault current to an acceptable level.

However, this dc reactor-type FCL cannot withstand against the fault current for a long period. Evoking a high dc voltage across the dc reactor during the fault period increases system losses and leads to use a bulky and expensive cooling system.

The dc reactor-type FCLs have less voltage drop during normal mode, but they can withstand only a limited period of fault current. The redundant volt-second on the dc reactor during the fault period saturates the core, and the FCL will lose the current-limiting capability

AC reactor-based FCLs use power electronics or mechanical switches to bypass the ac reactor during the normal operation mode Some topologies employ a series resonance LC tank in their structures [5]The series

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resonance FCLs are invisible during normal operation mode because the series ac reactor and capacitor are in resonance condition and their total impedance is negligible. During the fault, the power-electronic switches bypass the series capacitor and detuned the series resonance LC tank. Then, the ac reactor impedance limits the fault current. These FCLs have good capability to decrease the fault current but their onstate power losses and switching overvoltage are not acceptable. Some of them use an arrester in parallel with the power electronics switches to decrease the switching over voltages.

The dc reactor-type FCLs have good performance during normal operation mode but they cannot control the fault current successfully. On the other hand, ac reactor type FCLs can successfully decrease the fault current to an acceptable level but they have considerable losses during the normal operation mode. Also, switching between normal and fault condition causes high over voltages on the power-electronics switches. Furthermore, in order to have a proper FCL, it is recommended to combine the dc and ac reactor-based FCLs with superior advantages.

III. OPERATING PRINCIPLE

A) DC Operation Mode

In this case, the BSSFCL operates as a rectifier bridge that induces dc voltage on the series reactor and short circuits it by free-wheeling action. In fault inception, the increased fault cur- rent reaches the threshold current level and after this level, the controller changes the BSSFCL topology to ac mode

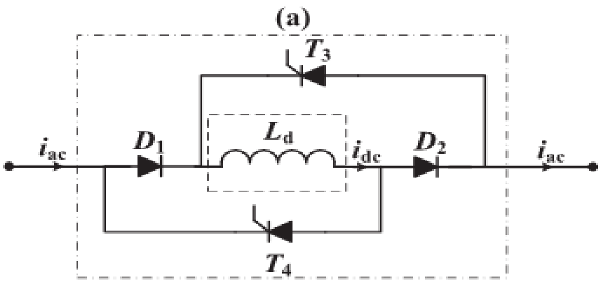

Fig : 3 - DC operation mode

B) AC Operation Modes

In this mode ,the peak of the line current reaches the per-defined value and the controller changes the proposed model's topology from the dc mode to the ac mode. In this case, D1 with T1 and D2 with T2 form two ant-iparallel switches that feed the reactor with ac voltage as shown in Fig. Similarly, T3 and T4 are turning off at first zero crossing current and the new circuit topology induces an ac voltage on the Ld .With this switching pattern in the fault interval , the impedance of the ac reactor increases and the fault current amplitude decreases to the specified level as shown in Fig 4.4 with a solid curve.

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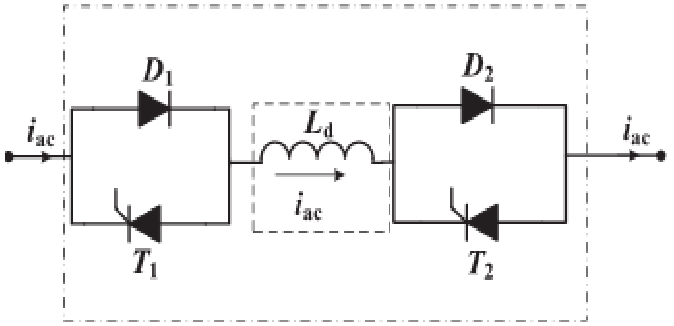

Fig: 4 -AC operation mode

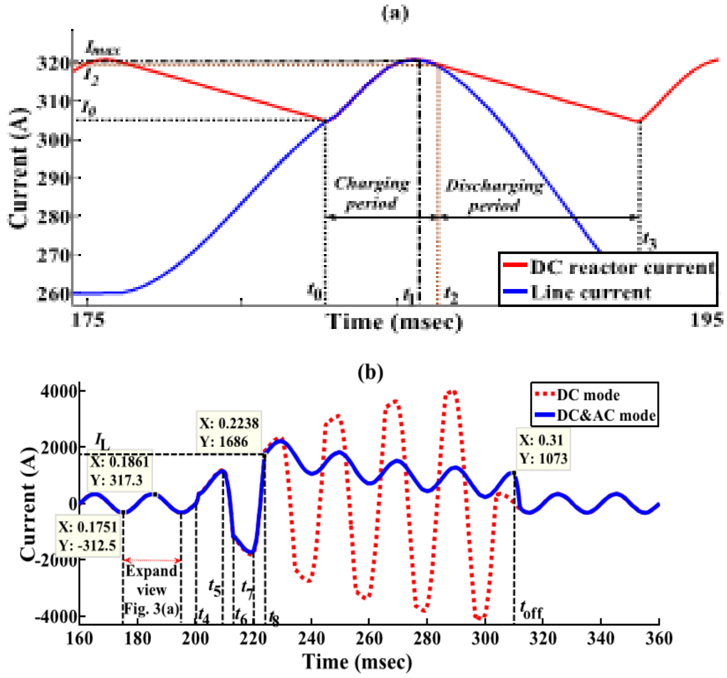

Fig:5(a)Expanded view of line and reactor current and (b) line current during normal and fault operation mode while operation of the BSSFCL in dc mode is shown with a dotted curve and operation of BSSFCL is in dc mode (normal Operation mode)and ac mode (fault operation mode)is shown with a solid curve

Fig.5(a) shows the expanded view of one cycle of the line and dc reactor currents during normal operation mode. This figure shows the effect of dc reactor resistance on the peak of the line current. Neglecting the small voltage drop of semiconductor de-vices, the total voltage drop across the BSSFCL is almost zero. So the BSSFCL has a negligible effect on normal operation mode**.**

IV. PERFORMANCE ANALYSIS

The simulation results are obtained using 20-kV network data as listed in Table I and system is simulated for 900 ms

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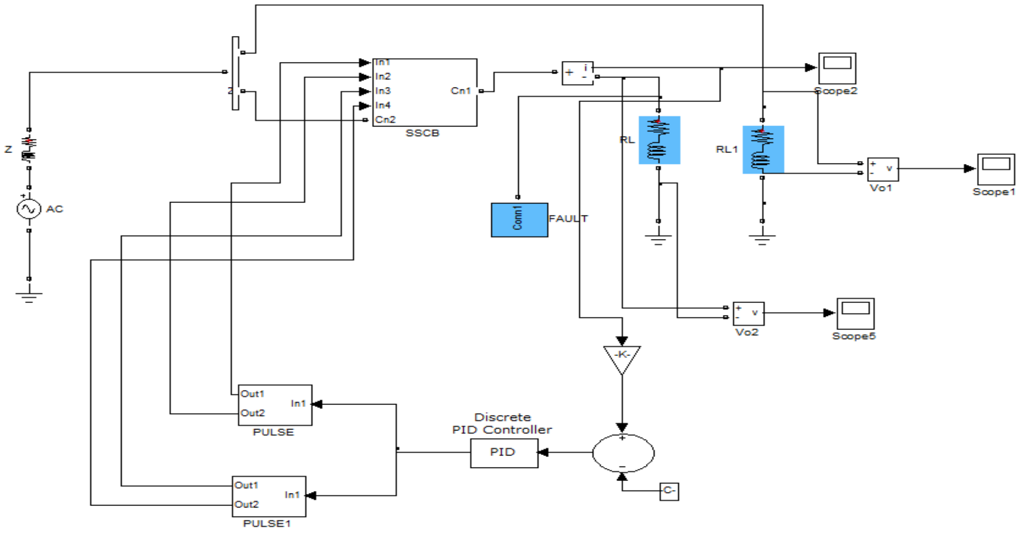

Fig:6- Fault current limiting with closed loop system

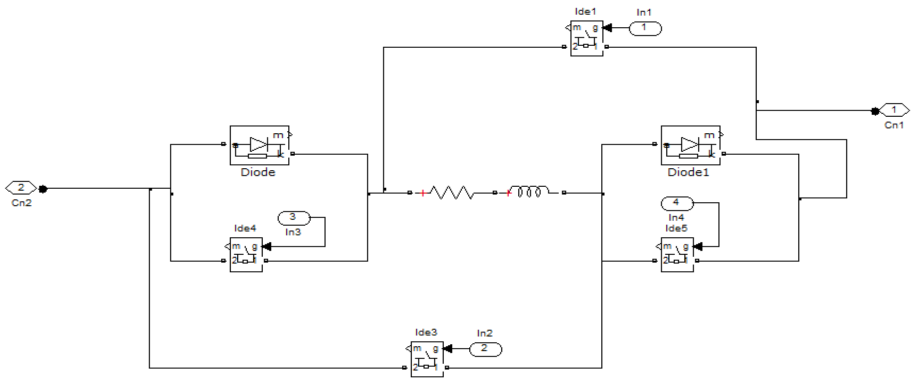

Fig :7- Bridge type solid-state fault current limiting circuit diagram

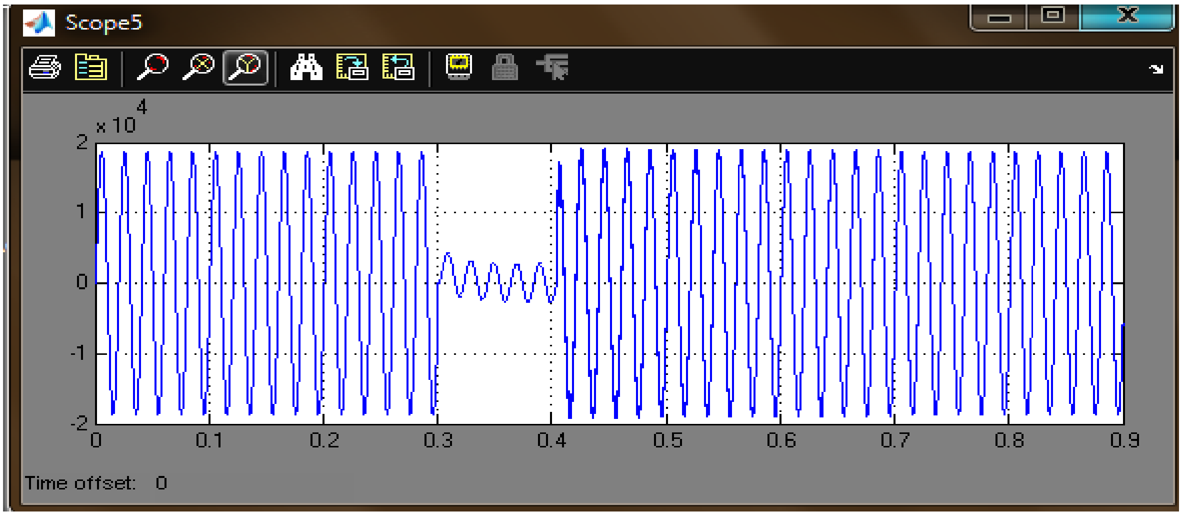

Fig: 8 - Output voltage in Bridge type solid-state fault current limiting condition

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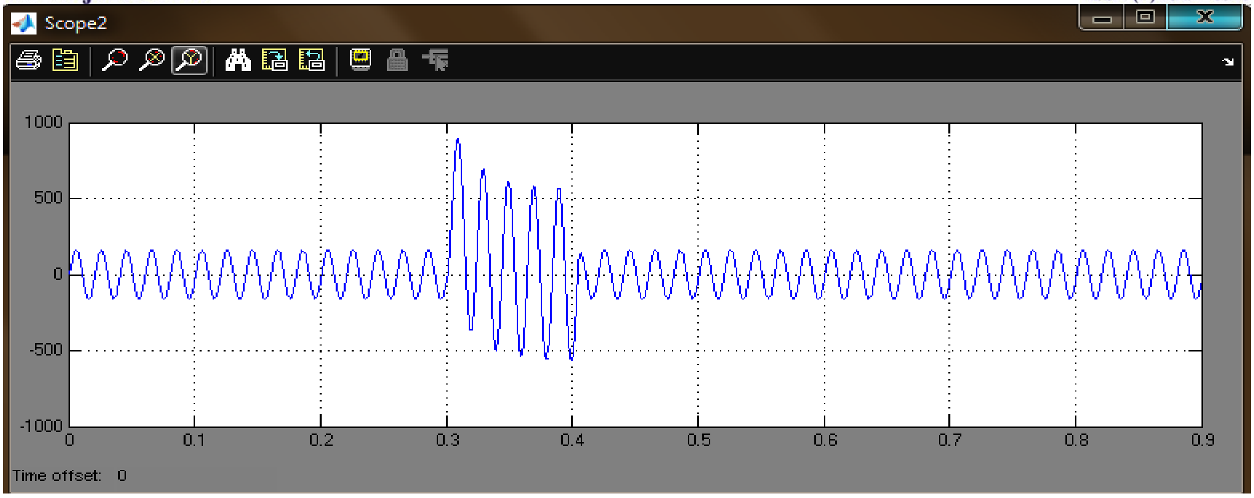

Fig:9 - Output current Bridge type solid-state fault current limiting condition

Table -1: Comparison of output fault current

BTSSFL	Vin	Io
AC mode	20kv	6300A
DC mode	20kv	10000A
Fault current limiting mode	20kv	1120A

Table:2 -Comparison of output current with & without controller

BTSSFL	Vin	Io
Without controller	20kv	1120A
With controller	20kv	500A

V. CONCLUSIONS

In this paper, proposed BSSFCL structure, including a reactor, which can operate in ac and dc modes, has been proposed. The first peak of the fault current amplitude has been controlled and the system can work in the safe operation region. In the proposed BSSFCL, the switching over voltages have been decreased. This topology can protect switches against over voltages. After fault removal ,only one reactor is used. This reactor causes fast recovery via changing the topology from the ac mode to the dc mode and results in fast recovery to the initial state. These characteristics of the proposed BSSFCL increase the reliability of the electrical network, and the BSSFCL is suitable for higher voltage applications by considering coordination problems.

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