Implementation of optimized Parallel-LC-Resonance Type Fault Current Limiter

L.Sunitha¹, M.Sai Kumar²
¹M.Tech student, PEES, S.R. Engineering College, India
²Assistant Professor, EEE, S.R. Engineering College, India

Abstract: Fault current Limiter (FCL) supplies low rate solutions to substitute conventional defense devices. This protects other equipment on the process from getting damaged by way of improper fault currents. FCL raised to become excellent alternative to scale down rankings of circuit breakers and may limit the electromagnetic stress in related equipments. In this paper a brand new parallel resonance Fault current Limiter (FCL) has been modified in a way that may sustain the magnitude of fault present and manage it in a favored worth. The operation is based on making use of parallel L&C resonance circuit with a resistor that reduce transient time and a pair of thyristors for controlling the value of fault current. Additionally, the proposed FCL doesnot use a superconducting inductor which has high building cost. Analytical evaluation for this structure is presented in detail, and simulation outcome are acquired to validate the effectiveness of this structure. The simulation results are obtained utilizing MATLAB/SIMULINK.

Keywords- Parallel-Resonance Type Fault Current Limiter (FCL), Point Of Common Coupling (PCC), Power Quality (PQ), Semiconductor Switch.

I. INTRODUCTION

Power utilities spend millions on system upgradation to maintain new circuit breakers. Fault Current Limiter (FCL) is a low-cost solution which can protect the system as well as, is financially beneficial. Fault Current Limiter (FCL) is the technological answer to the problem of higher level of short circuit current where system amplification takes place and replacement of whole protectionswitchgear is not achievable. FCL is the topic of active research worldwide. There are different types of FCLs that are either very expensive or have not achieved the technical suitability yet. For hugely reliable power supply, fault current limiter (FCL) is becoming a vital part in the modern power system. The conventional technology used at present to clear the fault is based on circuit breaker (C.B) with over current relay [1]. The circuit breaker (C.B) which is rated for the full systems short circuit current is located to ensure the adequate protection of the power system during permanent faults. The typical operational time delay of practical circuit breaker ranges from limited cycles to several seconds. During this time, only the system impedance can limit the fault current. Current limiting device is required to be introduced into the powersystem for limiting the fault current before opening the circuit breaker [2]. The implementation of FCLs in electric power systems is not restricted to suppress the amplitudes of the short circuits; they are also utilized to variety of performances such as the power system transient stability enrichment, power quality improvement, reliability improvement, increasing transfer capacity of system equipment, and inrush current limitation in transformers [3]-[6]. An ideal FCL should have the following characteristics [7]:

- Zero resistance impedance at normal operation;
- No power loss in normal operation and fault cases;
- Large impedance in fault condition;
- Quick appearance of impedance when fault occurs;
- Fast recovery after fault removed;
- Reliable current limitation at defined fault current;
- Good reliability;
- Low cost;
In [8] and [9] a new parallel resonance type FCL has been introduced. Due to its novel topology it can put up with magnitude of fault in a constant value by inserting high impedance in fault time. Fault current limiters have many different topologies comprising superconducting FCLs, resonance-type FCLs and solid-state FCLs. Superconducting FCLs bounds the fault current by using asuperconducting coil. In the normal system operating condition, this coil has little resistance. When a shortcircuit fault occurs, the resistance of this coil will risedrastically. Thus the current will be limited [10]. Resonance types FCLs limit the current by the resonance between their capacitor and inductor during the fault.

II. RELATED WORK

In this paper, a new structure for a parallel-LC resonance type FCL is introduced. The proposed FCL uses a resistor in series with a capacitor, and therefore, it can simulate load impedance during fault. By this way, it can limit the fault current level near to pre-fault condition. From the power quality point of view, by equating fault current and before-fault line current, the voltage of the point of common coupling (PCC) will not experience considerable change during fault condition, and power quality will improve. In comparison with the previously introduced resonance-type FCLs, this FCL does not use a superconducting inductor in the resonant circuit, and as a result, it is simpler to manufacture and has lower cost. Analysis and design considerations for this FCL are presented, and matrix laboratory (MATLAB) software is used to solve the resulted formulas. The circuit operation in the normal and fault conditions is simulated by using MATLAB/Simulink software.

III. RESONANT TYPE FCL

Proposed topology of fault current limiter is shown in fig.1. This circuit consists of a two resonant branch, two thyristors T1 and T2, and a resistance. During normal process of circuit, the thyristors are off and the resonant branches are short circuit (C1 and L1, C2 and L2). The relationship between (C1, C2) and (L1, L2) are shown in equations (1), (2) as follow:

\[ jL_1\omega = \frac{1}{jC_1\omega} \Rightarrow \omega = \frac{1}{\sqrt{L_1C_1}} \] ..........................(1)

\[ jL_2\omega = \frac{1}{jC_2\omega} \Rightarrow \omega = \frac{1}{\sqrt{L_2C_2}} \] ..........................(2)

So, in this case FCL have equivalent impedance that it can limit the fault current. The magnitude of corresponding impedance and also the magnitude of fault current depend on the resistance magnitude and trigger phase angle of thyristors. Without using resistance when thyristors activated the equivalent impedance will be infinite. Equations (3), (4) show the FCL equivalent impedance.

\[ jL_2\omega = \frac{1}{jC_2\omega} \Rightarrow \omega = \frac{1}{\sqrt{L_2C_2}} \Rightarrow Z_1 = \infty \] ..........................(3)
\[ jL_1 \omega = \frac{1}{f_2 \omega} \Rightarrow \omega = \frac{1}{\sqrt{L_2 C_2}} \Rightarrow Z_2 = \infty \ldots \ldots \ldots (4) \]

Fig.3. shows the single-phase circuit topology of the proposed FCL. It is essential to use a similar circuit for each phase in a three-phase distribution system. This structure is composed of two main parts which are as follows:

**Bridge Part:** This part consists of a rectifier bridge containing D1-D4 diodes, a small dc-limiting reactor (Ldc), a self-turnoff semiconductor switch (such as a gate turnoff thyristor and an insulated-gate bipolar transistor) and its snubber circuit, and a freewheeling diode (Df).

Resonance Part: This part contains a parallel LC resonance circuit (Lsh and Csh) (its resonant frequency is equal to power system frequency) and a resistor Rsh in series with the capacitor. The bridge part of the proposed FCL functions as a high-speed switch that changes the fault current path to the resonance part when the fault occurs. Observably, it is possible to substitute this part with an anti-parallel connection of two self-turnoff semiconductor switches. Using a diode rectifier bridge has two advantages compared to two anti-parallel switches as follows:

- This structure practices only one controllable semiconductor switch which operates in the dc side instead of two switches that operate in the ac side. The control circuit is simpler because of no need for ON/OFF switching in the normal operation case.

It is possible to use a small reactor in series with the semiconductor switch at the dc side. This reactor plays two roles as follows:

- It is snubber for a semiconductor switch.
- It is as a current limiter at first moments of fault occurrence. However, placing the dc reactor inside the bridge makes the voltage drop on it because of dc current ripple.

However, the current ripple is low, and consequently, the voltage drop caused by it is not significant in comparison with the feeder’s voltage. Current ripple and voltage drop equations are studied entirely in [15]. It is important to note that high-rating semiconductor switches are commercially available with current rating up to 24kA and voltage rating up to 4 kV. Also, it is possible to use more or less series and/or parallel self-turnoff switches considering high current and voltage levels. The semiconductor switch needs a suitable snubber circuit for its protection, which is not shown in Fig. 3 for simplicity.

![Fig.3. Single-phase power circuit topology of the proposed parallel-resonance-type FCL](image-url)
Considering (1) and the small value of the dc reactor in this structure, the total power losses of the proposed structure develop a very small percentage of the feeder’s transmitted power.

![Fig. 4. Control circuit of the proposed FCL.](image)

Fig. 4 shows the control circuit of the proposed FCL. In the normal operation of the power system, the semiconductor switch is ON. Therefore, \(L_{dc}\) is charged to the peak of the line current and behaves as a short circuit. Using the semiconductor devices (the diodes and semiconductor switch) and the small dc reactor causes a minor voltage drop on the FCL. When a fault occurs, the dc current becomes greater than the maximum permissible current \(I_0\), and the control circuit detects it and turns the semiconductor switch off. Therefore, the bridge retreats from utility. At this moment, the freewheeling diode \(D_f\) turns ON and provides a path for discharging the dc reactor. When the bridge turns OFF, the fault current passes through the parallel resonance part of the FCL. Accordingly, large impedance enters to the circuit and prevents the fault current from growing. In the fault condition, the parallel LC circuit starts to resonate. In this case, because of resonance, the line current oscillates with large magnitude. These oscillations may lead to damaging system equipment or putting them in stress. Though, by placing a large inductor in the line current path, the proposed structure in this paper has very low losses in the normal condition, because the inductor is bypassed by the bridge part. Also, by choosing proper values for the resonant circuit, the proposed FCL limits the fault current in a way that the power system is not affected by the fault. In such a condition, there will not be any considerable voltage sag on the PCC voltage as shown in Fig. 5.

![Fig. 5. Single-Line Diagram of the Power System.](image)

IV. CONCLUSION

In this paper, a new topology of parallel-LC resonance-type FCL that comprises a series resistor with the capacitor of the LC circuit has been
presented. The analytical analysis and design deliberations for this structure have been presented. Maintaining DG's current level to its pre-fault one during a short circuit condition, the parallel-resonance-type FCL can restore the re-closer to fuse coordination, which was lost because of the overview of DG's. Whereas the resonance type FCL can be designed so as to restore the coordination, but it will decrease DG's current during normal condition and thus its application might be undesirable.

REFERENCES


BIODATA
L. Sunitha pursing M.Tech in PEES from Sr Engineering College, Warangal, Telangana, India.

M. Sai Kumar working as Assistant Professor, Department of EEE in Sr Engineering College, Warangal, Telangana, India.