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Fault Current Limiter for a Distributed Power System

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***Abstract*– The up-gradation of an Electrical power generation network results in higher levels of short circuit fault current. Thereby, the existing protection equipment like circuit breakers, isolators and fuses become under capacity and not capable of withstanding higher short circuit currents. Thus the system is highly vulnerable to the adverse effects of short circuits. Replacing the whole protection switchgear is not feasible technically and economically. The solution in such a situation is an equipment called Fault Current Limiter (FCL). The concept of FCL is not new but the most suitable FCL is an on going research subject. This paper covers the prevailing aspects of FCL, the types of FCL, the research progress and at present the most viable FCL solution for industrial purpose at 6.3kV system in Pakistan.**

***Index Terms*– Fault Current Limiters, Short Circuit Current, Triggered Fault Current Limiter and Distributed Power System**

I. INTRODUCTION

POWER utilities spend millions on system up-gradation and to maintain new circuit breakers. Fault Current Limiter (FCL) is a cheaper 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 augmentation takes place and replacement of whole protection switchgear is not feasible. FCL is the subject of active research worldwide. There are different types of FCLs that are being actively designed, some have been marketed but are either very expensive or have not achieved the technical acceptability yet.

II. CURRENT RESEARCH WORK

Considerable research has been undertaken worldwide to design and implement a most suitable FCL. A differentiation between the different types of FCLs is that of passive and active FCLs. Passive FCL is the one that uses already high source impedance during normal operations and fault conditions while active FCL brings a fast increase of source impedance in the circuit during the fault [1].

A. Triggered Current Limiter

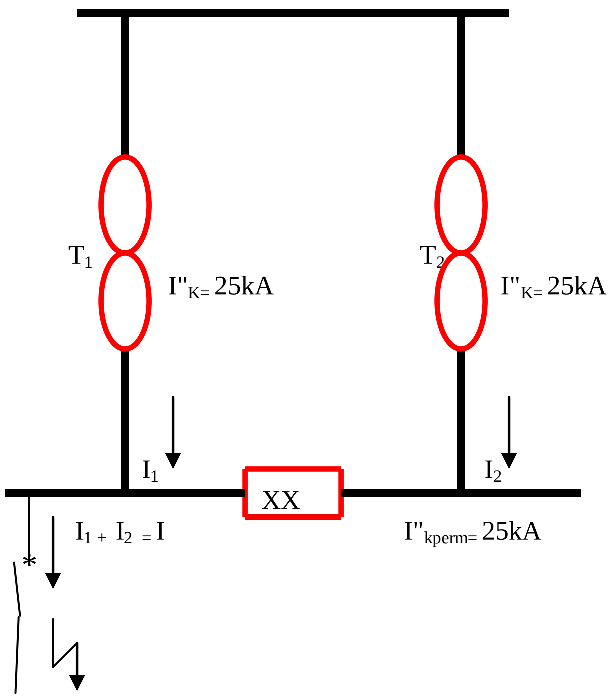
The triggered current limiter is an arrangement of a switch that is quick opening, can conduct high rated current, has a low switching capacity plus a fuse with a high rupturing capacity arranged in parallel. The short opening time is achieved by storing a small charge that works as stored energy and is released, during short circuit conditions, to trip the main conductor. After opening of the main conductor the current diverts towards the parallel fuse where it is limited after 0.5 milli second and is completely shut down at the next voltage zero.

This kind of limiter is being used in the industry with considerable success. This limiter is employed in different arrangements like between an independent power supply and public network, between bus-bar couplings, with reactors in parallel and several limiters together. A detailed study has been presented [2] where the triggered current limiter successfully limits the fault current and the associated over voltage surges during the process. The triggered current limiter is being designed and marketed by ABB Germany and Areva T & D, both having considerable success. [3]. The triggered current limiter has been proved experimentally to be effective in mitigating short circuit current in comparison with the conventional current limiting techniques [4].

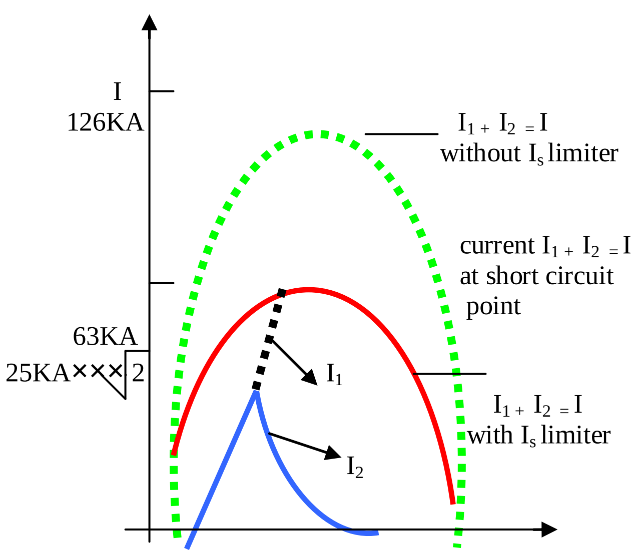
In Fig. 1 a typical arrangement of a triggered current limiter that is used between a bus tie, has been shown. The impact on the short circuit current is also described. The triggered current limiter is being marketed with considerable success by two well known manufacturers, ABB and Areva T & D with continuous design improvements. ABB being the pioneer has more market presence internationally [16].

B. Solid State Fault Current Limiter (SSFCL)

Solid state limiters use a combination of inductors, capacitors and thyristors or gate turn off thyristors (GTOs) to achieve fault current limitation. Recent research work is going on to develop a suitable SSFCL for industrial purpose. A resonant type solid-state limiter has been proposed and discussed with considerable experimental success [6]. A capacitor is connected in parallel with an inductor and a pair of thyristors. The thyristors are switched on only during short circuit conditions that forces most of the current to flow through the inductor. The different laboratory models have been presented of the SSFCL but commercially as an industrial solution still further work needs to be done. The available models have high cost and cooling requirements [7]. Some of the disadvantages of the SSFCL are very high cost, higher losses and the components used are still inadequate for very high magnitude fault current [8].



(a)



(b)

Fig. 1: (a) Single line diagram of a bus tie for a system with a $I''_{K=}$ 25kA and with I_s (b) limiter Is-limiter impact on short circuit [5]

A. Magnetic Fault Current Limiter (MFCL)

This design of FCL is intended to overcome some of the short comings of the traditional FCL [9]. This kind of FCL uses two magnetic devices connected in series with opposing magneto motive forces. The material used for the core should have a low value of saturated flux density compared to permanent magnet in order to keep the core in saturation under normal operating conditions. Similar to the SSFCL, the MFCL is also under active research [10]. Zenergy Power USA is actively designing MFCL however there price is still quite higher in comparison to triggered current limiters.

B. High Temperature Superconducting Fault Current Limiter (HTSCFCL)

This kind of the limiter has the potential advantage of the loss less conductor being used in normal conditions that becomes highly resistive under fault conditions [11]. Superconducting FCL have no resistive or ohmic losses during normal conditions but there exists uncertainties regarding cooling requirements, regular maintenance and very high cost that are some of the factors that have reduced their effectiveness in practical applications [12].

Several reviews and updates have been carried out world wide to summarize the research progress of FCL technology. A number of projects round the world are in progress, some are being funded by state agencies to develop the FCL technology further and make it feasible as an actual industrial solution [18], [19].

III. CASE STUDY

A case study of an industrial unit (a cement plant in north of Pakistan) having an installed load of 20MW that is being fed by its own furnace oil based generators. The company has recently installed a 7MW waste heat recovery steam turbine-generator and additionally a public utility connection having a sanctioned load of 17MW. Due to these three power sources being synchronized together, the short circuit fault level in the plant will rise above the safety limits of the installed protection switchgear, that were originally supposed to be sufficient for single power source, furnace oil based generation. Thus the whole electrical network is vulnerable to heavy breakdowns during short circuit conditions.

A complete short circuit study of the network was carried out. Since growth of a power system results in increased available short circuit current, the momentary and interrupting ratings of new and existing equipment on the system were checked if the equipment can withstand the increased short circuit current. Fault contribution from generators and motors was taken into consideration. The data for the network was collected in the form of data sheets and load lists and supported by relevant technical manuals. For short circuit calculation, network calculation tool PSSTM SINCAL [13] was used. Single line diagram of the whole network, present and proposed, was prepared. The voltage level of the plant is 6.3KV, while public utility voltage is 132KV that is being stepped down to 6.3KV with the help of 20 MVA transformer installed at the plant grid station. All generators, transformers and MV motors were referenced as per their data sheets/name plates. Cable impedances were chosen from “Pakistan cables catalog” [14].

The short circuit calculations were carried out using IEC60909 standards [15]. The voltage factor c=1.1 is used for 3-phase and 1-phase (maximum) short circuit calculation at medium voltage and C=1.05 for low voltage network. The initial 3-phase (maximum) symmetrical short circuit ($I''k$) is referred to the thermal stress of breaker and is used in the selection of circuit breaker. Peak current (Ip) determines the mechanical stresses of the breaker.

The method used for calculation is based on the introduction of an equivalent voltage source at the short circuit location. The short circuit study was carried out keeping in view all generation scenarios, for example all three power sources in synchronization, any two power sources in synchronization and any one power source generating electricity independently. According to the findings of the short circuit study when public utility connection is in service, the short circuit current exceeds the allowed capacity of 31.5kA at the grid station busbar. Whereas when public utility connection is not in service than the short circuit does not exceed the allowed limits of the circuit breakers.

IV. PROPOSED SOLUTION

It is clear from the short circuit study findings that the existing switchgear is inadequate when all the three power sources are in operation together. It is technically and financially not feasible for the plant to replace the complete protection switchgear. To reduce the short circuit level of the network, it is recommended to install an FCL of rating equal to the breaker rating at 6.3kV side of grid transformer i.e. 2500A. The FCL will be installed in the inter bus connection of the system between grid MV bus and junction bus. The protection purpose is to limit the fault current at any place of the voltage level to the permissible value of I_K” = 31.5 kA_{rms} (rating of the most 6.3kV switchgear) and I_K” = 25 kA_{rms} (rating of the grid MV bus (Fig. 2).

From the review in section II of the FCL technology it is clear that the modern current limiters are still at the developmental stage therefore the most feasible solution for an industry in Pakistan is triggered current limiter.

It is proposed that a triggered current limiter, with a capacity 2500A and short circuit withstand capability of 31.5kA be installed. Triggered current limiters that are marketed to date are 10 times cheaper than the SCFCL and MFCL that are marketed. Presently ABB and Areva (T&D) formerly G&W Electric manufacture and market the triggered current limiter with the names as Is-Limiter and CLiP respectively. Price of the both the products for 6.3kV range is similar. Based on the market survey the Price of Is-Limiter 2500A, 31.kA, 50Hz for 6.3kV application is around 130,000 Euro.

In this particular application the Is-Limiter is suggested as ABB has more proven track record of successfully implementing the Is-Limiters world wide. The Is-Limiter will be placed in the bus tie of grid station and the cement plants own power plant. The system can be operated in parallel as well with the current limiter in service.

The Is-limiter will have multiple benefits for the Cement plant:

- Its installation will avoid complete revamping of the grid station.
- It will protect the under rated protection switch gear.
- The life time of the grid equipment will increase manifold.
- It will reduce downtime during power system short circuits.

V. CONCLUSION AND FUTURE WORK

In this paper we have discussed the present status of fault current limiter technology. While a case study of an industry in Pakistan has been carried out and the most feasible solution has been proposed. It is concluded that whenever a power system is upgraded the short circuit fault level increases, the most feasible solution is the installation of FCL. But choosing the right kind of FCL is an on going research topic. The solid state, superconducting and magnetic FCL are under active research world wide but the most feasible solution at present is triggered fault current limiter, mainly due to technical simplicity and economics.

Some of the areas where future work can be carried out are:

- In Pakistan many utilities and industries have carried out expansion of networks but very few have installed the FCL mainly due to two reasons; lack of awareness technically and financial impact. In this area future work can be carried out to study more systems in Pakistan and suggest them suitable current limiters to avoid huge system break downs.
- The system voltage of the case study in this research paper is 6.3kV while the maximum tested system voltage for the Is-Limiter is 38kV. For a higher system voltage Is-Limiter study can be carried out.
- Solid State fault current limiters, super conducting fault current limiters and magnetic fault current limiters are under active research. Some have been tested in the field but are extremely expensive. More research and scientific work should focus on making the solid state and super conducting fault current limiters more cost effective.

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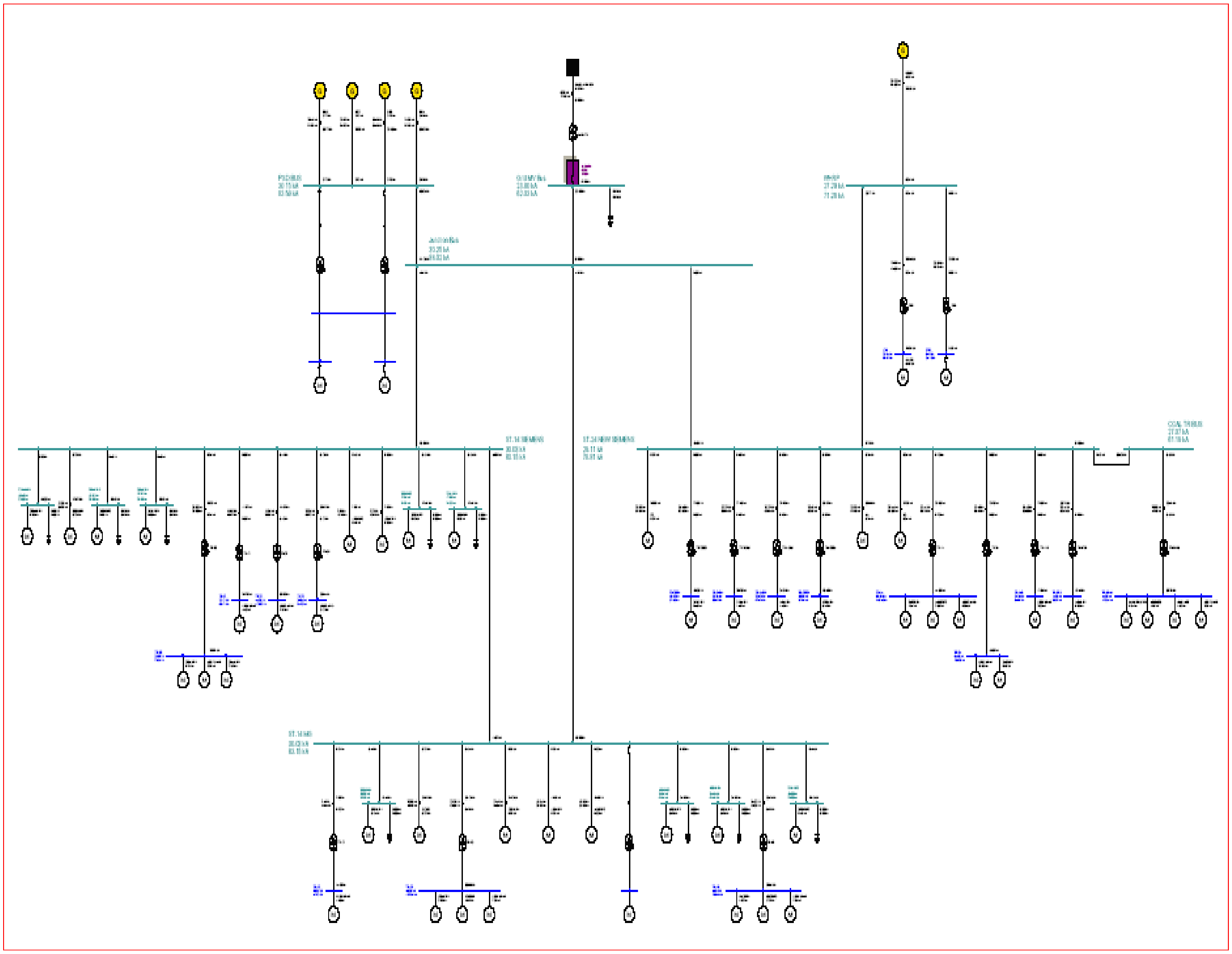

Fig. 2: PSS-Sincal PrintScreen- Single Line diagram of the whole network with the proposed Is-Limiter (in the middle) in the Grid Bus-bar

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