THYCON

Est.1968

TFCL

Thycon
Fault Current
Limiter

Introduction

There are many forms of electrical circuit protection including breakers and fuses but one attractive approach is limitation. Limitation, as opposed to breaking, involves the spontaneous increase of a preexisting but negligible impedance which immediately limits the fault current to a defined and innocuous level.
This can be achieved instantaneously with no delay, in contrast to breakers which have limited response times during which time the fault current may increase to the full value of the Prospective Asymmetric Peak. Breakers, when correctly designed and installed, will ultimately clear these currents but the faulted circuits and any included switch gear will inevitably be exposed to the fault current prior to opening and clearing.

Fault Current Limitation

There are different approaches to limiting a fault current. A promising technology for utility-level protection is the Super Conducting Fault Limiter which relies on a super conductor converting to a resistance when its current exceeds a certain level.This sophisticated technology nevertheless relies on costly cryogenics and is not for normal distribution protection.
For relatively low powers, PTCs (Positive Temperature Coefficient resistors) have been used for specialized applications. Like the super-conducting limiter, PTCs are self-acting but always have a residual resistance value which causes continuous losses and requires cooling.

Other limiters rely on active components, such as transistors, to open and to insert impedance (resistance or inductance) into the faulted circuit. These approaches are also fast and easier to maintain than super-conducting systems but they require electronic detection and control circuits and are not truly self-limiters.

Whatever the principle of operation, a limiter is simply inserted in series in the circuit to be protected. In normal operation it presents negligible impedance to rated current but this impedance suddenly increases when the current rating is exceeded.

The Thycon Fault Current Limiter

In recent years the proliferation of co-generation sites containing energy sources connected to the electricity grid has stirred renewed interest in fault current limitation techniques. The main disadvantages and reliability issues of present state-of-the-art technology can be summarized as follows:

- Impact on voltage regulation and stability
- Size/footprint
- Impact on system efficiency
- Penetration of stray alternating flux
- Impact on network switching surges
- Lack of fail-safe, passive technology

The development of the Thycon Fault Current Limiter is designed to address all of the above points. A typical fault current profile can be defined by two main variables: Peak and RMS magnitude. It was decided that by targeting the limitation of these two quantities separately the limitation technology could be made simpler and more reliable.

The Limiter, made up of interconnected network of diodes and a DC inductance, mitigates the initial asymmetric peak value of the fault current. Series fuses or circuit breakers, with appropriate selection and settings, can mitigate the RMS value of the fault current. Since mitigation techniques involve no detection (measurement) circuitry, power supplies or gating signals the technology is considered passive.

The TFCL takes the principle of limitation one step further by eliminating the need for control and detection while maintaining the principle of self-activation, inherent in super-conductors and PTCs. It consists purely of passive components. Fig. 1 shows the typical behaviour of the TFCL.

As can be seen from Fig. 1, the effect of the TFCL is “immediate” in that the very first fault surge (the asymmetric peak) is limited to a lower instantaneous peak value. Not even a fast acting fuse could limit current amplitude as quickly. A mechanical circuit breaker would in fact have no limiting effect on current amplitude and would let through the first three cycles or so, unattenuated. The TFCL is able to insert high instantaneous impedance for the critical first pulse and its impedance diminishes over the following cycles.

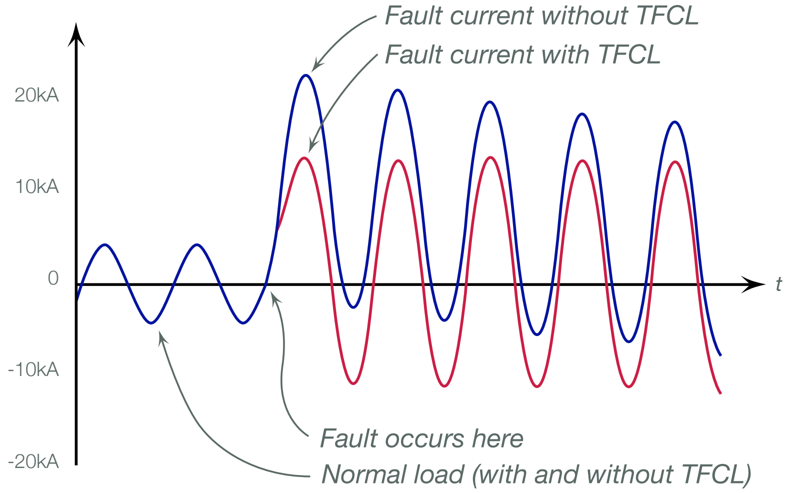
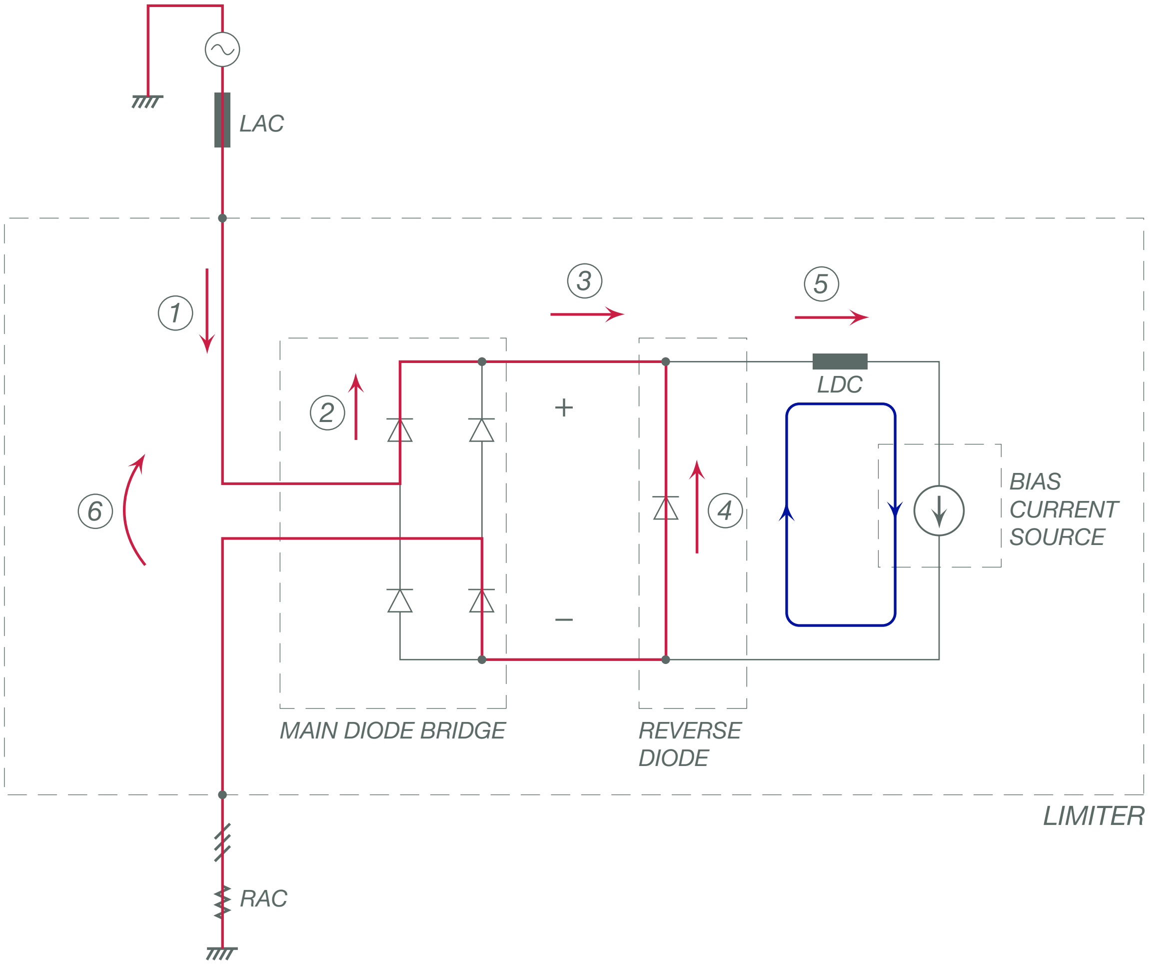


Fig. 1 – Fault currents with TFCL (red) and without (blue) in a faulted 50Hz network (10kA/div)

Operation of the TFCL

Under normal conditions, the TFCL allows the load current to pass from the supply to the load unhindered. Under fault current conditions, when the AC current increases in magnitude beyond full load conditions, the FCL begins to act as a high impedance such that the peak asymmetric pulse is completely eliminated.

The TFCL allows design flexibility and can be adapted to meet different application requirements. In particular, the initial peak current, the steady state current, as well as the time taken to reach these two values, are design variables



Operation under normal conditions – Figure A1 and A2

Figure A1 shows the circuit diagram of the Limiter connected to a three phase source and load. The current flow in each branch of the Limiter is indicated for reference to Figure A2. The red trace shows the current flowing from the source to the load.

The blue trace shows the continuous current generated by the bias source. The details of the bias source connection are omitted for simplicity, but can be considered typically as a diode rectifier with connections identical to the main diode bridge.

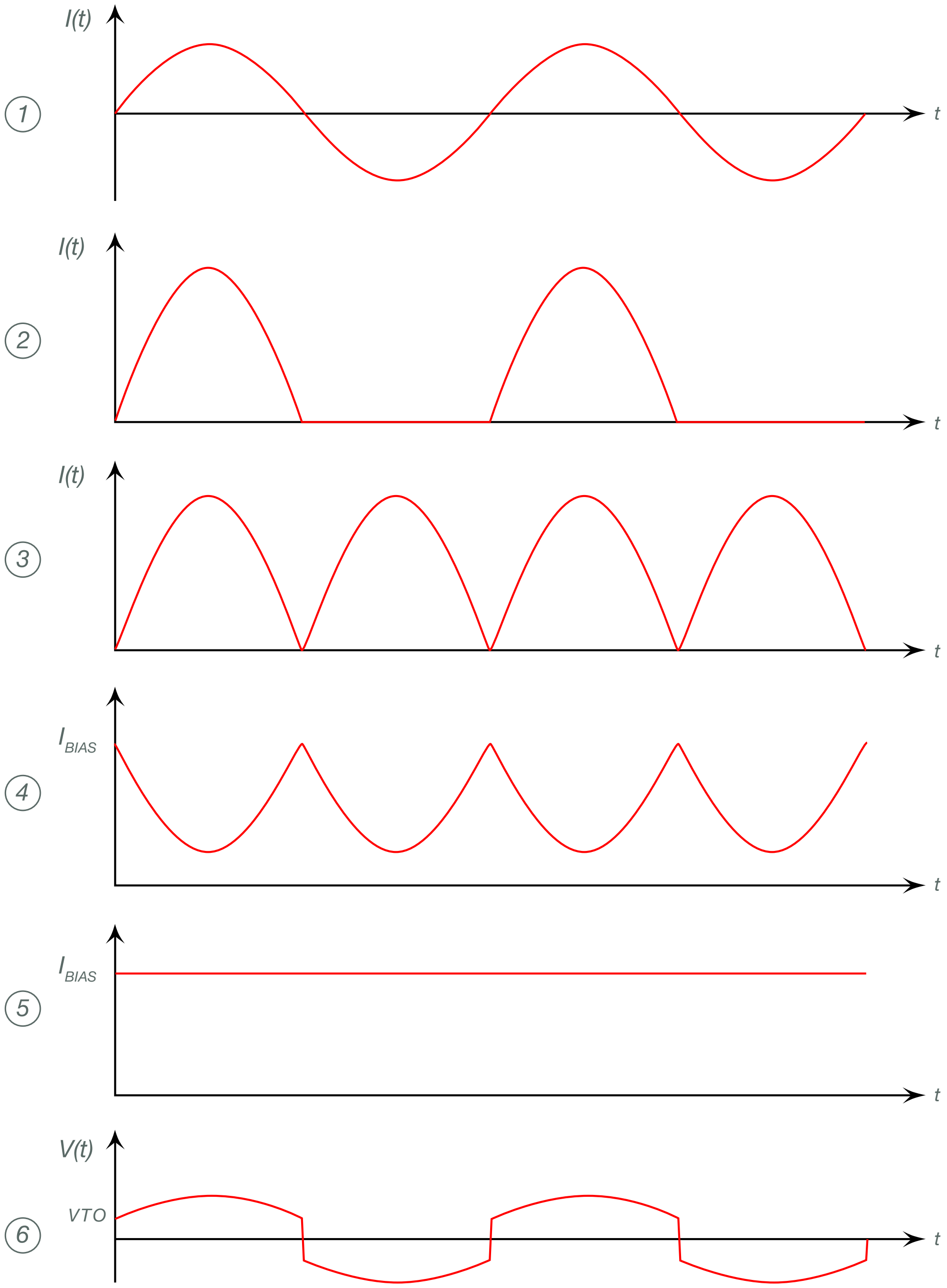
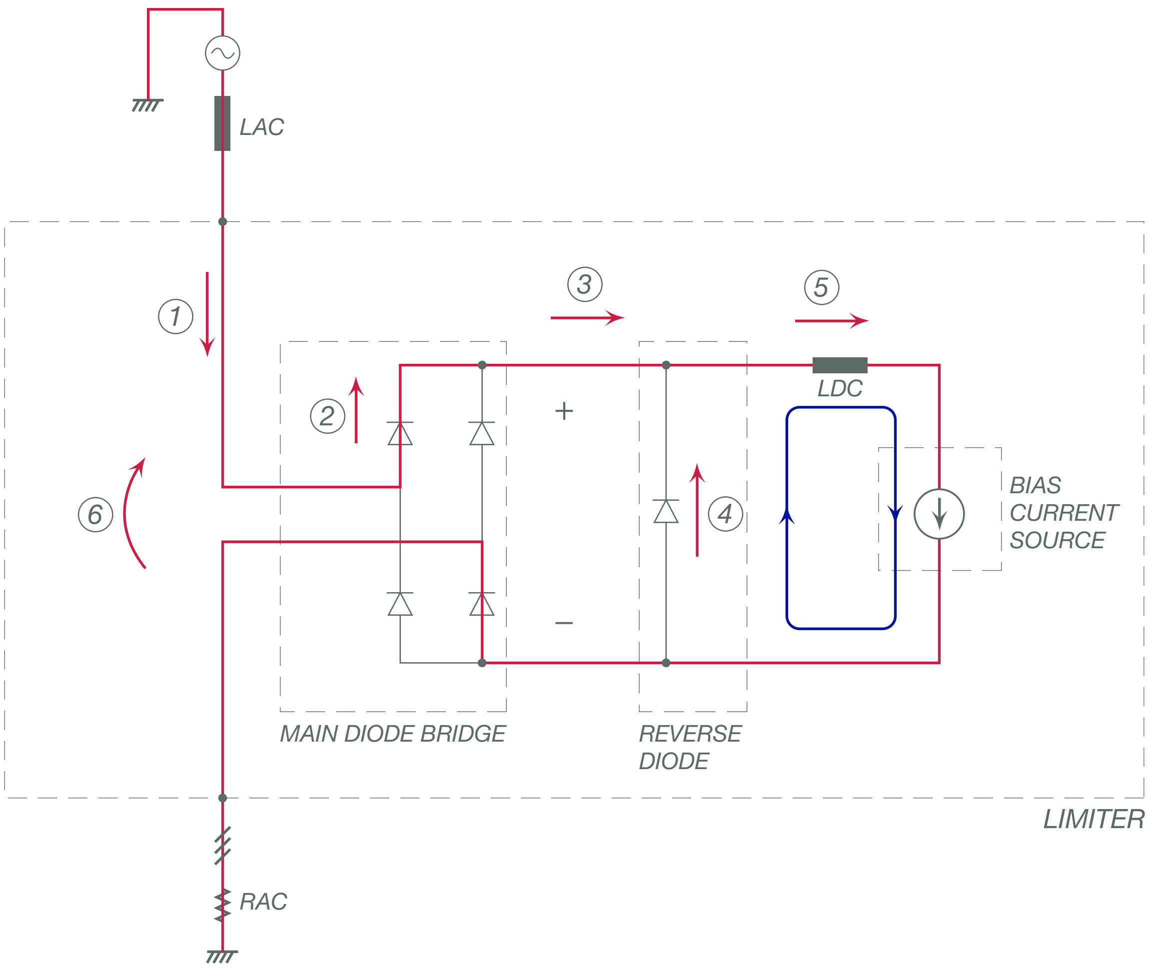


Figure A2 shows a two period graphical representation of the currents in each branch of the Limiter. The bias current (5) in this example is set at a value equal to the peak of the expected nominal AC load current.

The AC current (1) is below full load. The bias current source enables the reverse diode to remain in forward bias up to nominal load conditions, and effectively short circuits the DC poles of the main diode bridge.

Given that the forward voltage drop (Vto) of a typical diode is small compared to the network voltage, the DC voltage and AC voltage (6) pose a negligible series voltage drop to the system and current passes from the supply to the load in an unmitigated fashion.



Operation under fault conditions – Figure B1 and B2

Figure B1 shows the current flow during the transition of normal to fault conditions. In the event that the load current exceeds bias current the main diode is forced into a reverse bias state and the load current is forced through the limiting DC reactor.

The Limiter acts as a large impedance to the supply in this condition with the AC voltage drop across the Limiter (6) in proportion to the supply impedance by the ratio of AC to DC impedances.

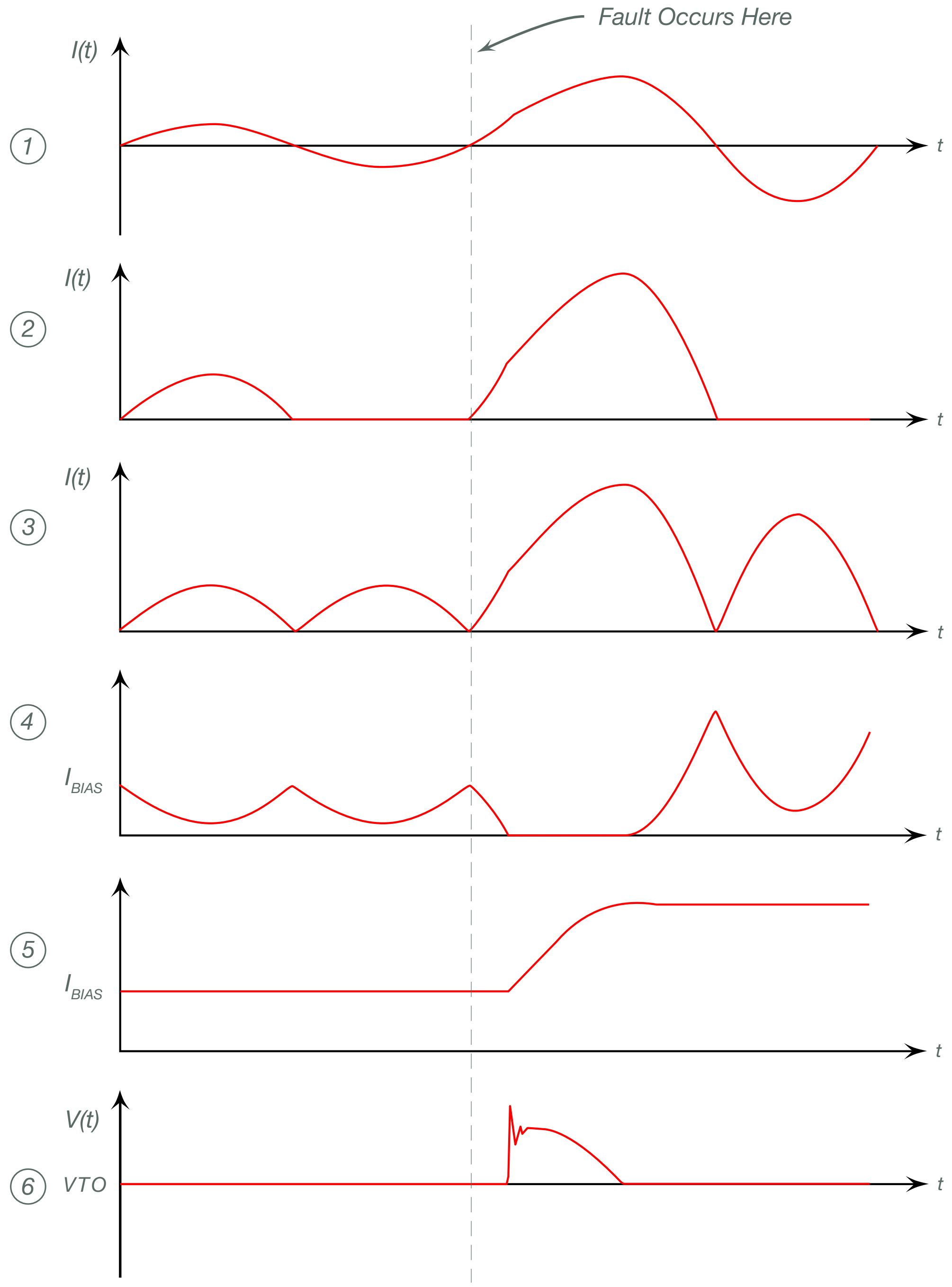
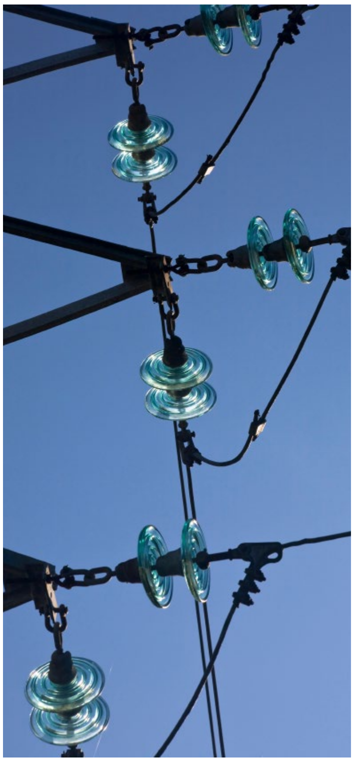


Figure B2

By the completion of the first half cycle, the DC reactor (LDC), is charged to the peak of the RMS fault current of the system. The discharge of the DC inductance returns the Reverse Diode to the forward bias condition and the circuit returns to normal operating conditions outlined in Figure A.

No further fault current mitigation takes place after this time and the series devices that are already part of the infrastructure, such as fuses or circuit breakers, act to open the circuit. The Limiter components are typically designed and selected in order to eliminate the asymmetry of the fault current of the system, so that the prospective peak fault current can never be reached. Overdamped or underdamped asymmetric fault current profiles can be achieved by increasing or decreasing the DC reactance (LDC), respectively.



Application Areas

The general area of application is that of fast fault limitation where breakers are already installed but unable to intervene with sufficient speed. These situations occur where existing installations are retro-fitted with additional energy resources as can be the case of co-generation or “renewables”. An example of such a retro-fit is shown in Fig. 2.

In Fig. 2, an existing grid (shown in black) is protected by a breaker designed originally to protect the distribution switchboard from bolted shorts of amplitude VGRID/(ZGRID). The addition of a co-generation plant (shown in blue) will add a prospective fault current of VGEN/(ZGEN) which will exceed the allowable fault rating of the switchboard.

A TFCL is therefore added in series with the co-generator to eliminate the asymmetric peak of thus preserving the existing switchboard installation without any modifications. This situation is common in any distribution grid because protection must be tightly co-ordinated with the network’s prospective faults to ensure rapid response of mechanical breakers.

Any subsequent power capacity added to the grid upsets this co-ordination. These problems can be solved by the introduction of Solid State Breakers (SSBs) which react within microseconds and allow additional generating capacity to be added with impunity. However, such installations are resettable but costly. Fuses, though clearing more quickly than mechanical breakers are, of course, not resettable and will not usually limit the asymmetric peak.

In cases where SSBs are deemed too costly, the fall-back solution frequently become the insertion of current limiting chokes which might, in turn, necessitate power factor correction. The TFCL allows the addition of power capacity without any changes to the existing installation and without the cost of sophisticated electronic breakers.

Conclusions

The Thycon Fault Current Limiter introduces a new dimension to system protection and power quality. Unlike existing PTC and superconducting limiters, it is easy to install, requires little maintenance and is low cost by nature. Unlike electronic limiters or breakers, it requires no control electronics and is fail-safe. Being self-acting and self-resetting, it is suitable for remote and isolated installations.

The TFCL is easily retro-fitted to existing networks where these are to be given additional capacity. It requires no separate power supply or feed-back links, no air-conditioning, no power-factor compensation or other correction techniques and does not perturb normal network operation with harmonics or voltage sags. It produces no arcs and is safe to use in explosive atmospheres. Being passive, it produces no EMI (electromagnetic interference) in normal operation.

Thycon also offers TFCL solutions in new installations and undertakes fault-level co-ordination studies where the TFCL can be used to enhance the performance of conventional mechanical breakers.

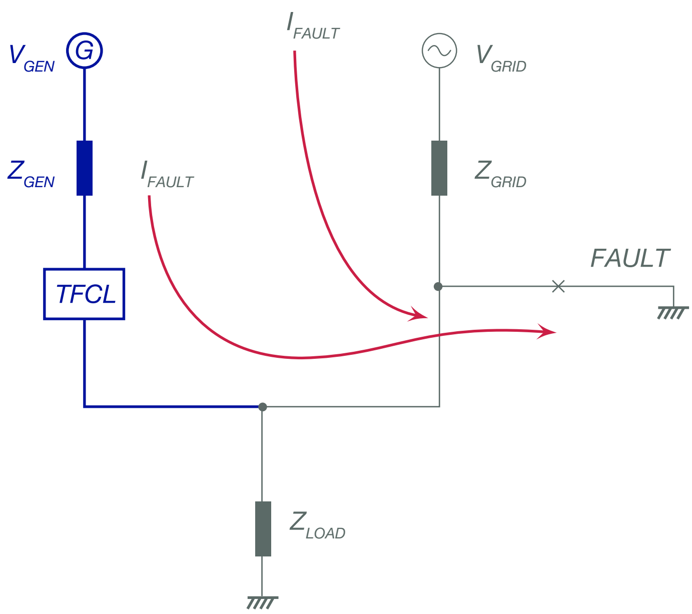


Figure 2

Benefits of the TFCL:

- Elimination of the peak asymmetric fault current, similar to Solid State Breakers
- Fast response of SSB but at much lower cost
- Limitation of let-through energy (similar to fuse)
- Self-limiting: no detection or control circuitry required
- System is based only on passive and non-active components
- Suitable for both LV and MV as well as single or three phase networks
- Protection can be co-ordinated with existing or supplemental breakers
- Optional “self test” functionality
- System stability with large limitation
- No impact on switching surges
- Negligible stray flux
- Small footprint

TECHNICAL INFORMATION

<u>ITEM</u>	:	<u>POWER MODULE (per phase)</u>			
CONNECTION	:	7			
PHASES	:	1			
RATED FREQUENCY	Hz :	50/60			
RATED VOLTAGE	kV :	<1	6.6	11	22
RATED CURRENT*	A :	2700	1500	700	700
DUTY CLASS	:	III			
INSULATION LEVEL	:	LI 0 AC 2	LI 35 AC 16	LI 48 AC 24	LI 87 AC 44
COOLING	:	AN			
AMBIENT TEMP MAX. 45	dC :	40			
DIMENSIONS W x D x H	mm :	1000 x 1200 x 600	1200 x 1200 x 800	1400 x 1400 x 800	1400 x 1600 x 800
TECHNICAL STANDARD	:	AS 60146			
<u>ITEM</u>	:	<u>DC REACTOR</u>			
		GAPPED IRON			
TYPE	:	CORE			
INSULATION LEVEL	:	LI 0 AC 3	LI 60 AC 20	LI 75 AC 28	LI 125 AC 50
TEMPERATURE CLASS	:	F			
COOLING	:	AN			
DIMENSIONS **	mm :	1000 x 1200 x 1400	1200 x 1200 x 1400	1400 x 1400 x 1400	1400 x 1600 x 1400
TECHNICAL STANDARD	:	AS 1028			
3 PHASE SYSTEMPERFORMANCE					
PEAK CURRENT LIMITATION (TYP.)	pu :	<2			
EFFICIENCY	% :	99			

* For higher currents parallel operation required

** Typical for 2 pu I peak limitation, generator supply. NOTE: cubicles stackable.

THYCON