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ASPECTS REGARDING THE USE OF ELECTRONIC POWER DEVICES IN POWER GRID

BY

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Abstract. Custom power devices are generally used to power sensitive consumers who need higher energy quality. This paper will exemplify some of the custom power devices used in distribution networks. The case study will highlight the solid-state current limiter effects on an electrical network by simulating a medium voltage network. By installing a solid-state current limiter, the value of the short-circuit current decreases; thus, the electrodynamic forces and thermal stresses supported by the components of the electrical network are reduced.

Keywords: Custom power devices; solid-state current limiter; short circuit current; circuit breaker; overhaul.

1. Introduction

In recent years, the development of power electronics has allowed the use of semiconductor components in applications used in high and medium voltage networks. The power semiconductor components are thyristors, GTO thyristors (Gate Turn OFF Thyristor), IGBT transistors (Insulated Gate Bipolar

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Transistor), power transistors (BJT), power MOSFET transistors (Metal Oxide Semiconductor Field Effect Transistor), (Asare *et al*., 1994; Adam and Baraboi, 2004).

Applications that use semiconductor power components used in medium voltage networks are known as custom power devices.

Custom power devices are divided into two categories: network-reconfiguring type, used to change the network configuration in the event of an event (short circuit, power interruptions, over and under-voltages, etc.) and compensating type, used to enhance the power quality.

Some of the custom power devices used in medium voltage networks are listed in Table 1.

Table 1
Custom Power Devices

Device	Type
Solid-State Current Limiter (SSCL)	network-reconfiguring
Solid-State Breaker (SSB)	
Static Transfer Switch (STS)	
Distribution Static Compensator (DSTATCOM)	compensating
Dynamic Voltage Restorer (DVR)	
Unified Power Quality Compensator (UPQC)	

2. Custom Power Devices for Network-Reconfiguring

The main network reconfiguring type custom power devices are solid-state current limiter, solid-state breaker, solid-state transfer switch (Ghosh and Ledwich, 2012; Kumar *et al*., 2017; Desale *et al*., 2014).

A. Solid-State Current Limiter

A solid-state current limiter is a device connected in series with the medium voltage line. Under normal operating conditions of the power line, the SSCL impedance has a low value to notinfluence the value of the current flowing through it. In fault conditions, the SSCL impedance increases rapidly to limit the short-circuit current (Ghanbari and Farjah, 2012).

The scheme of the solid-state current limiter consists of two GTO thyristors mounted in antiparallel and a limiting coil, L_m, Fig. 1. To protect the thyristors can be added a snubber circuit, Fig. 1*a*, formed by a resistor R_S and a capacitor C_S or a ZnO surge arrester, Fig. 1*b*. The solid-state current limiter is connected at the beginning of the power cable, after the circuit breaker, CB. The fault current limitation is proportional to the value of the limiting coil reactance.

In normal operation, the current flows through the GTO thyristors, which are in conduction. When a fault current is detected, the GTO thyristors are blocked, and the current flows through the limiting coil, L_m, and the circuit breaker, CB, because its switching time is longer than the blocking time of the thyristors. Then, the short-circuit current limited as value by the inductance L_m is interrupted by the circuit breaker, CB. When the SSCL reactance changes, a sudden voltage spike occurs at its terminals, limited by the snubber circuit or by the surge arrester.

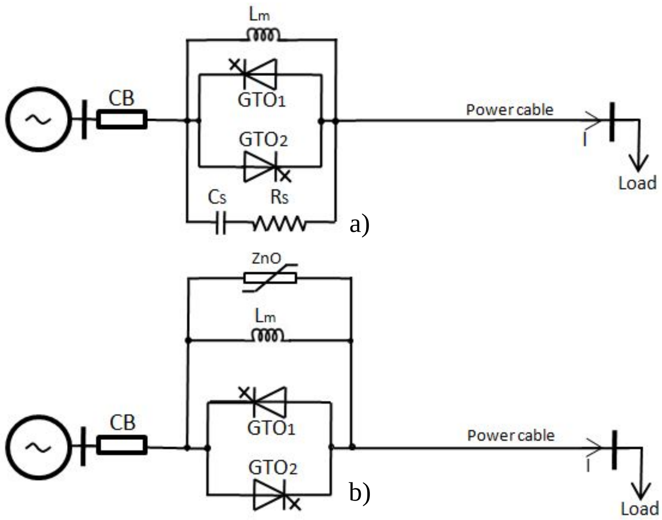

Fig. 1 – Diagram of an electrical network with solid-state current limiter.

The solid-state current limiter can be used successfully if the short-circuit current is greater than the breaking capacity, I_{br}, of the circuit-breaker.

The solid-state current limiter can reduce the maintenance costs of circuit breakers because the duration between two overhauls depends on the short-circuit current intensity and the number of short-circuit trips. Thus, for a medium voltage low oil circuit breaker, which trips four times at a short circuit current greater than half the circuit breaker breaking current, $I_{scc} > 0.5 \cdot I_{br}$, a circuit breaker overhaul is required. If the short-circuit current is limited to a value between $0.25 \cdot I_{br} < I_{scc} < 0.5 \cdot I_{br}$, the number of trips allowed until the next revision is double. In the case of a medium voltage vacuum circuit breaker, it is recommended that when the maximum number of trips is reached, depending on the short-circuit current; the vacuum interrupter chamber to be replaced (Schneider Electric, 2018).

The installation of a solid-state current limiter on a power line influences the line protections by the additional impedance introduced in the circuit. Suppose the protections are not adapted to the new conditions. In that case, some short-circuit, which would normally be eliminated by the instantaneous overcurrent protection, will be eliminated by the defined time overcurrent protection. This delay increases the thermal stress to which the network elements are undergone (Atanasoaei, 2019; Atanasoaei, 2020).

B. Solid-State Breaker

The role of the solid-state breaker is similar to that of the mechanical circuit breaker, respectively, to connect, maintain and interrupt the current through the protected circuit in which it is installed. The solid-state breaker connection mode is shown in Fig. 2.

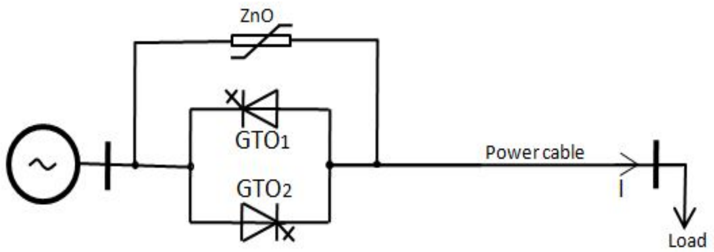

Fig. 2 − Diagram of an electrical network with solid-state breaker.

The current is interrupted by blocking the two GTO thyristors (Kulworawanichpon, 2003). The ZnO surge arrester is used to protect the thyristors against overvoltages that may occur.

In order to increase the short-circuit breaking capacity, a limiting coil, L_m and two antiparallel thyristors can be added, Fig. 3.

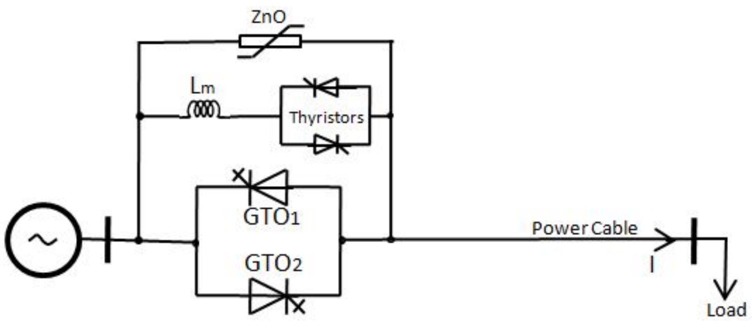

Fig. 3 − Diagram of an electrical network with a solid-state breaker with current limitation.

C. Static Transfer Switch (STS)

A static transfer switch (STS) is used to supply important consumers, sensitive to voltage fluctuations.

To perform its function, two power sources are required, (Schwartzenberg and Doncker, 1995; Moschakis and Hatziargyriou, 1995). The static transfer switch is made of two pairs of thyristors connected in antiparallel. A surge arrester, ZnO, can be used to protect the thyristors against overvoltages, Fig. 4.

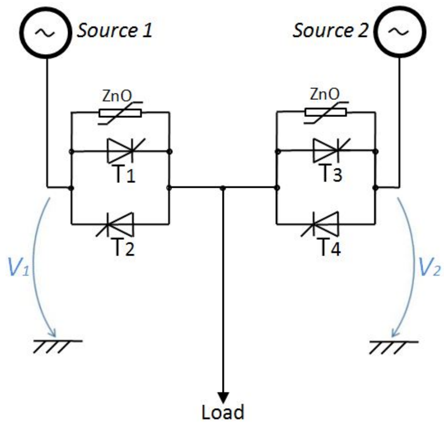

Fig. 4 − Diagram of an electrical network with static transfer switch.

In normal operation, the consumer is supplied from source 1, via T_1 and T_2 thyristors. When a power interruption or an over / undervoltage occurs, the STS switches the consumer power supply from source 1 to source 2.

3. Case Study

It is considered a medium voltage electrical network supplied by an alternative voltage source, with the nominal voltage U_n= 6 kV, in which a solid-state current limiter is installed. Fig. 5. An industrial consumer is supplied by a 5 km long power line. The industrial consumer needs an active power of 3 MW and reactive power of 1.5 MVAr. The SSCL limiting reactance is X_L=0.6 Ω. The power cable has a specific resistance r_0=73 mΩ/km and specific reactance x_0=76 mΩ/km. The SSCL device is connected at the beginning of the line, after the circuit breaker (CB).

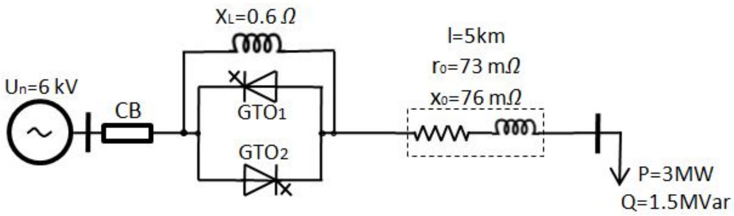

Fig. 5 − Single line diagram of the experimental electrical network.

In Fig. 6 can be observed the evolution of the instantaneous short-circuit current in case it occurred at 3 km from the beginning of the line. In the case "without SSCL", the maximum instantaneous value reached by the short-circuit current is 8674 A. In the case "with SSCL" the maximum instantaneous value reached by the short-circuit current is 6114 A. The fault elimination time is 35 ms, which represents the opening time of the circuit breaker. It is observed that by using an SSCL, the short-circuit current value decreases.

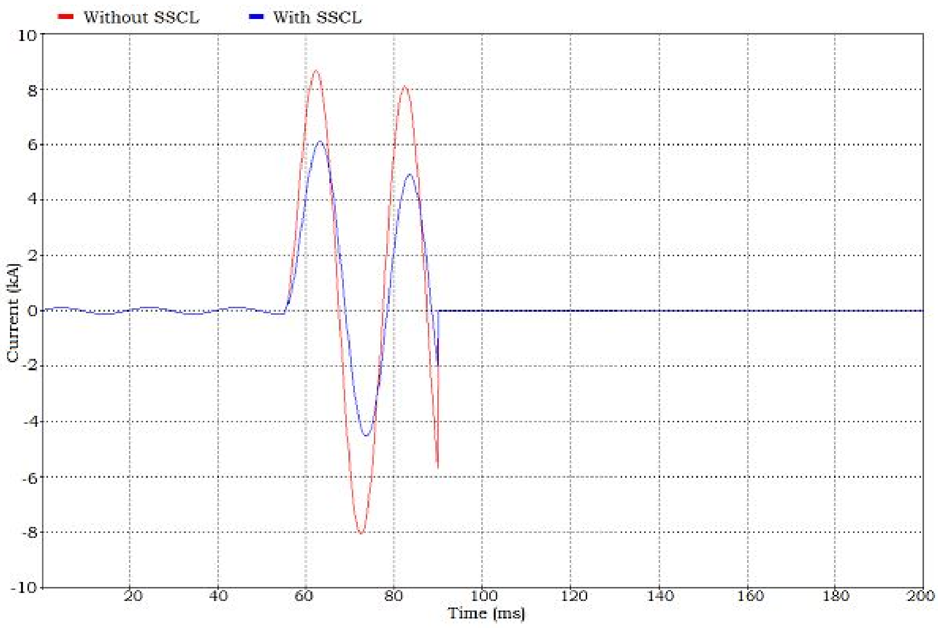

Fig. 6 − The evolution of the instantaneous value of the short-circuit current with and without SSCL.

According to (ICMENERG, 1995), the number of disconnects allowed between two repairs for a low oil circuit breaker depends on the intensity of the short circuit current. For a low oil circuit breaker with a rated current of 2.5 kA the number of short-circuit trips allowed between two repairs varies according to Table 2.

Table 2
Number of Short-Circuit Disconnections Allowed Between Two Overhauls

Circuit breaker type	Nominal current I_n (kA)	Breaking current I_k (kA)	Number of short-circuit disconnections		
			$I_n<I<0.25 \cdot I_k$	$0.25 \cdot I_k<I<0.5 \cdot I_k$	$0.5 \cdot I_k<I<I_k$
Medium voltage low oil circuit breaker	2.5	19.2	20	8	4

By using a solid-state current limiter, the value of the short-circuit current decreases. In Fig. 7 can be observed the evolution of the effective value of the short-circuit current, at the moment of disconnection, with and without SSCL, along the entire length of the line.

The evolution of the effective value of the short-circuit current, at the disconnection moment, with and without SSCL, for defects km by km, throughout the length of the line is shown in Fig. 7. The value of the short-circuit current is different depending on the location of the fault.

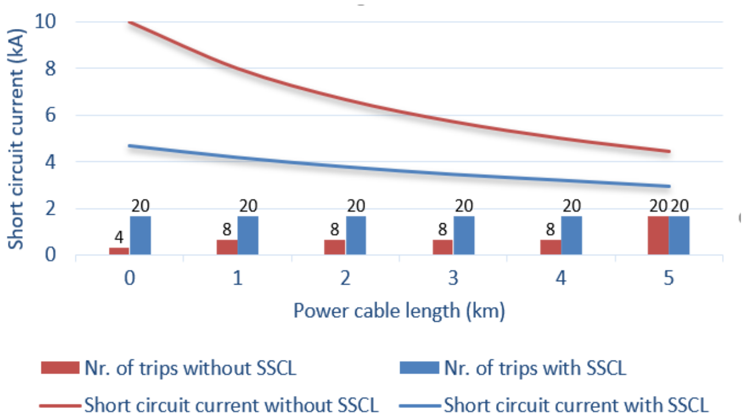

Fig. 7 − Maximum number of trips allowed until the next overhaul of the circuit-breaker, depending on the value of the short-circuit current.

It can be seen that when SSCL is used, the maximum number of short-circuit trips allowed between two overhauls is 20, regardless of where the defect occurred. If SSCL is not used, the maximum number of short-circuit trips allowed between two repairs decreases when the place where the short circuit occurred is approaching the beginning of the electric line, Fig. 7.

4. Conclusions

Custom power devices are generally used to power sensitive consumers, who need a better quality of the power supplied. This paper is demonstrating some of the custom power devices used in distribution networks. In the case study, by simulating a medium voltage network, the effects of a current limiter on an electrical network were highlighted.

It is found that by using a SSCL, the short-circuit current value decreases. Thus, the maintenance costs of the circuit-breakers are reduced during their lifetime. The maximum number of trips until the next overhaul, which depends on the intensity of the disconnected short-circuit current, increases in the presence of the static current limiter.

The solid-state current limiter can also be used successfully in medium voltage power lines where the short-circuit current is higher than the breaking capacity of the circuit-breaker on these lines.

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ASPECTE PRIVIND UTILIZAREA DISPOZITIVELOR ELECTRONICE DE PUTERE ÎN REȚEAUA ELECTRICĂ

(Rezumat)

Dispozitivele *custom power* sunt utilizate, în general, pentru alimentarea consumatorilor sensibili, care au nevoie de o calitate a energiei electrice mai ridicată. În această lucrare sunt exemplificate câteva dintre dispozitivele *custom power* utilizate în rețelele de distribuție. În studiul de caz, prin simularea unei rețele de medie tensiune, se evidențiază efectele care le are asupra funcționarii acesteia prezența unui limitator de curent. Dispozitivele *custom power* oferă posibilitatea modificării rapide a configurației rețelei și îmbunătățeste calitatea energiei electrice furnizate, prin reducerea întreruperilor și a golurilor de tensiune, reducerea distorsiunilor armonice, îmbunătățirea factorului de putere.