HIGH PERFORMANCE VACUUM CIRCUIT BREAKER FOR CAPACITIVE LOAD OPERATIONS

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ABSTRACT

The power consumption is constantly on the rise nowadays, and the grow of renewable generation makes the regulation of network parameters and its stability more challenging than in the past. In this scenario the use of capacitor banks is becoming more and more important, not only for the power factor correction purpose, but also for managing the peak energy demand in the more on daily basis. Capacitive current switching is critical for the circuit breaker as well as for the network to handle, due the fact that it can cause disturbances on the grid: high inrush current and voltage transient.

In this paper we will be discussing about a new smart high performance Circuit Breaker capable of providing extended capacitive current switching performance for protection and control of capacitive loads without inrush current and voltage transients.

1 INTRODUCTION

In today's power distribution architecture and industrial applications with more and more decentralized power generation, medium voltage capacitor banks are crucial apparatus to assure network stability, reliability of energy supply and reactive power compensation.

In addition, in more recent years, unlike in the past, the spread of wind generators in interconnected plants has increased the need for further control and regulation systems, increasing the need to frequently switch capacitive loads both to comply with operational regulation and regulatory needs.

Unfortunately, capacitor switch operations involve technical challenges like inrush currents, prestrikes and inrush frequencies which can heavily impact the lifespan of the assets connected to the network and the power quality of the energy distributed.

Energizing a capacitive load produces a large temporary charging current of the capacitor called "inrush current". This can produce oscillation and disturbances of the line voltage.

Disconnection of capacitor is always a critical point because at the interruption of the current the voltage stress is the highest and can be associated with a high recovery voltage with the risk of voltage breakdown and escalation.

Historically additional mitigation components such as inrush current reactors, current limiters and surge arresters have been in usage. This results in increased costs and space requirements and also increased power losses

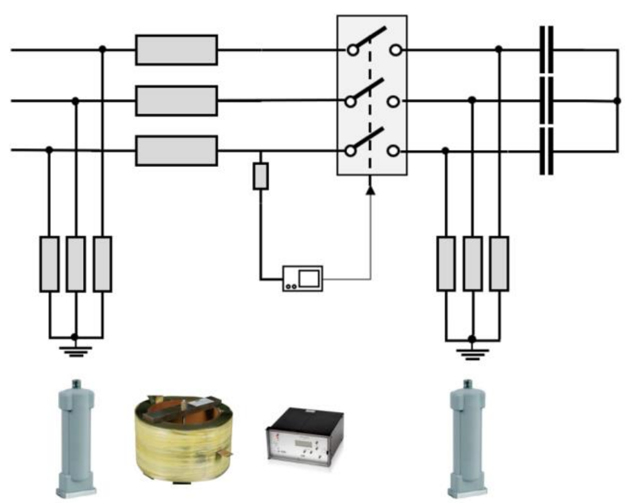

Figure 1: Traditional equipment for mitigation switching transients

Supervisory equipment such as point on wave controllers have been used to mitigate the effects connected to capacitor switching operation. However, this does not solve the problems completely in a sustainable way, because the repeatability of the switching time of the Circuit Breaker is a big challenge. Generally, the switching operations are controlled by the external signal trigger without full control on the main switching elements and without considering the possible impacts due to environmental conditions and aging of the apparatus (temperature, wear and tear etc.).

In several capacitive load switching application it is quite common to have the need to perform 500-1000 operations/day. This is in contrary to the normal load switching requirement of a Circuit Breaker, which is a few hundred or a few thousand operations in the entire life span. It is also important to note that apart from the high number switching operation requirements, the high inrush current and the high frequency voltage transients, not only stress the Circuit Breaker but also impact the useful service life of all the equipment connected to the network. This also creates EMC disturbances difficult to be handled by the equipment and by the whole network.

Hence, a “transient free” switching apparatus with very high and stable performances over the lifetime is required for highly demanding capacitive load switching applications.

2 ADVANCED CIRCUIT BREAKER FOR SMART OPERATIONS

A new and smart solution have been implemented in the new generation of MV apparatus integrating advanced mechatronics control system technology designed for MV circuit breaker including:

- Independent single-phase control
- Innovative vacuum interrupters
- Servomotor driven Technology
- Dedicate kinematic chain/transmission
- Closed loop control for position, speed and torque
- High accuracy time resolution for precise zero crossing switching
- Analog inputs availability for gathering measurement from the MV network
- Custom configuration Flexible logics
- Embedded native diagnostic

As part of the apparatus platform released for dedicated applications [5,7], this breaker has been recently released. This unleashes the benefits coming from the point of wave control provided by accurate switching capability combined with the ability to operate each phase independently.

Figure 2: Figure 1: Advanced Smart Circuit breaker

A dedicated switching control able to be triggered from the upstream Medium voltage waveform sync. was combined to a new family of Vacuum Interrupter resulting in the capability of the apparatus to precisely switch the Vacuum interrupter contact system with a variation of < 200us including the mechanical and environmental deviations from one operation to the other.

This new feature enables the execution of an accurate and reliable zero voltage crossing close control without transient during the capacitor closing and opening operations with contact system opening far from the zero crossing of the current eliminating, in this way, any restrike possibility

Theses series of apparatus are Vacuum circuit breakers intended for indoor installation in air-insulated switchgear, specifically designed for capacitive current switching application.

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Figure 3: High performance breaker with independent servomotor control

The synchronization strategy on Close is based on a pure zero voltage close control designed for center star floating capacitor bank (Y ungrounded). Thanks to the high time resolution of the control combined with the high accuracy of motor control, this breaker can precisely match the point on wave connection.

This breaker implements the 2+1 closing sequence according to IEEE Std 1036-2010 (Guideline for application of shunt capacitors).

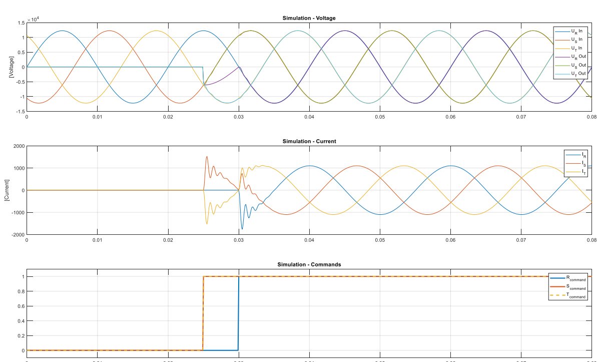


Figure 4: 2+1 Close sequence of the breaker

The apparatus precisely closes phase B and C (S and T) at the peak of the R signal reference (phase to ground) that corresponds to the 0 Ph-Ph voltage on phase B and C (S and T). At this point the star of capacitance sees the energization of the two capacitors Cb and Cc energized at the 0 voltage. A quarter period later the breaker closes Ca (here the star center and consequently the Ca capacitor connection reach the phase to ground voltage of phase A (R).

The described point on wave switching process leads to a very limited pre-arching and very effective inrush current limitation.

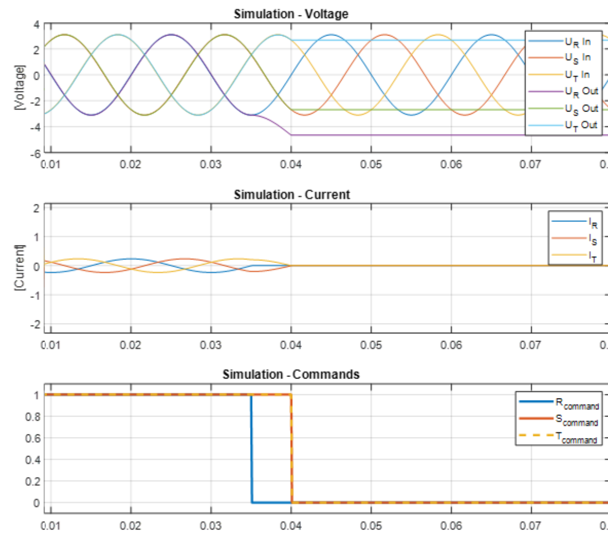


Figure 5: Open Sequence of the breaker

The synchronization strategy for opening is defined in order to limit the behavior that happen when the capacitor is de-energized: the current extinction occurs at current zero and the voltage is at the peak. This is normally a stressful situation on interrupters because it has to withstand the high recovery voltage without reignition (better known in literature as restrike).

Thanks to the high time resolution of the control system, the breaker operates the contact system separation at a proper phase angle ensuring that when the current extinguishes the contact system gap will limit and avoid any probability of restrike.

3 RATING AND PERFORMANCES

The breaker complies with the IEC 62271-100 standard for MV Circuit breaker with specific additional testing procedure specific to extended making and breaking, mechanical and environmental performances.

Rating	Value	Remarks/Add
Rated voltage	36-38 kV	50/60 Hz Av.
Rated current	1250 A	Capacitive
Short-time current	3 sec. 31,5kA	2 sec. 40KA
M&B	Peak making current 94,5 kA	Breaking current (rms) 31,5kA
Withstand voltage	Power Frequency 95kV	Lightning impulse 185kV

Table 1: Breaker ratings

The making and breaking tests have been referred to IEC62271-100 and as required for apparatus based on intentional non-simultaneous switching strategy, during making realizes the insertion of two phases and a third phase 90° later, higher peak making current (94.5kA, 3 times 31.5kA) was tested.

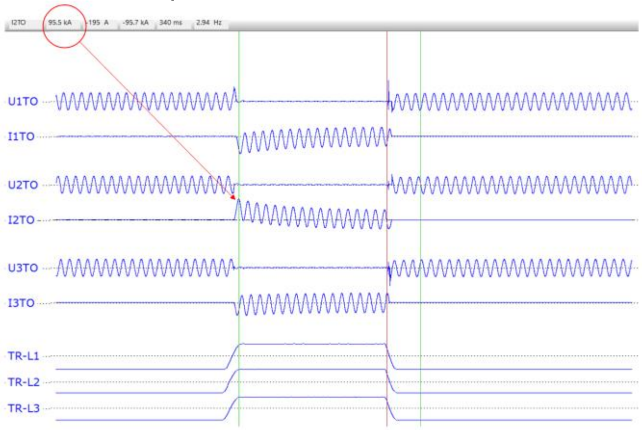


Figure 6: Making and Breaking test snapshot

High and low temperature tests were also carried out in accordance with IEC60068 2-1 and 2-2 with adding additional pass-fail criteria focusing on the capability to keep stable the contact timing performances.

In the following picture it is verified the capability of the control system to keep stable the contact system timing comparing the behavior at ambient temperature with the one obtained at low and high temperature.

Additionally, the capacitive test was applied to the breaker not only with the scope to verify if the Circuit breaker was able to satisfy the standard test criteria but also to verify the performance of the breaker as well.

In Figure 7 is reported the behavior of the fast compensation loop of control system (torque, speed and position) that enables the drive to react to friction changes keeping constant the circuit breaker timing allowing to keep stable performance even with environmental changes.

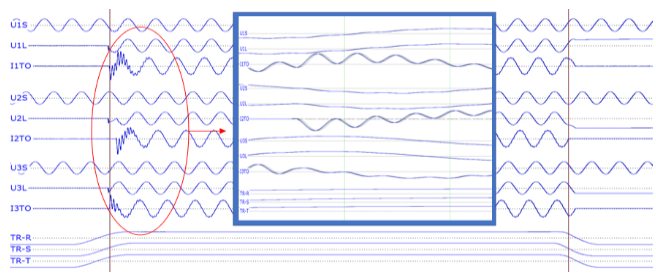
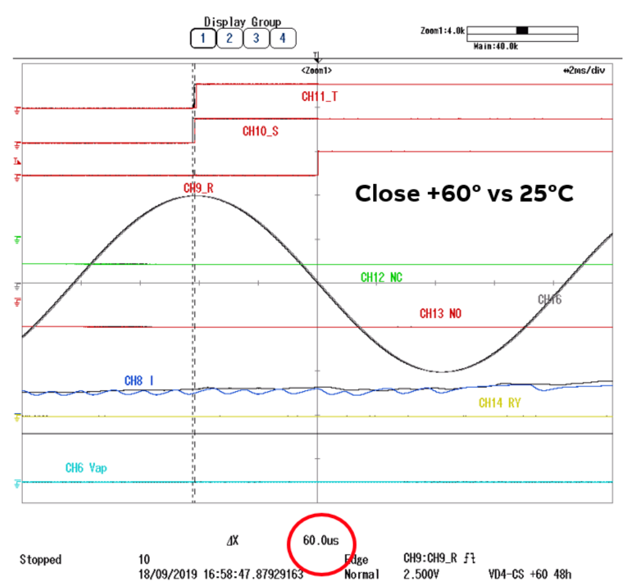


Figure 7: Repetitive Capacitive Close Open test overlapped

In Figure 8 it can be appreciated the performance of the insertion of the capacitive load without any inrush currents thanks to the high level of repeatability of the contact system timing given by implementation of the closing strategy described.



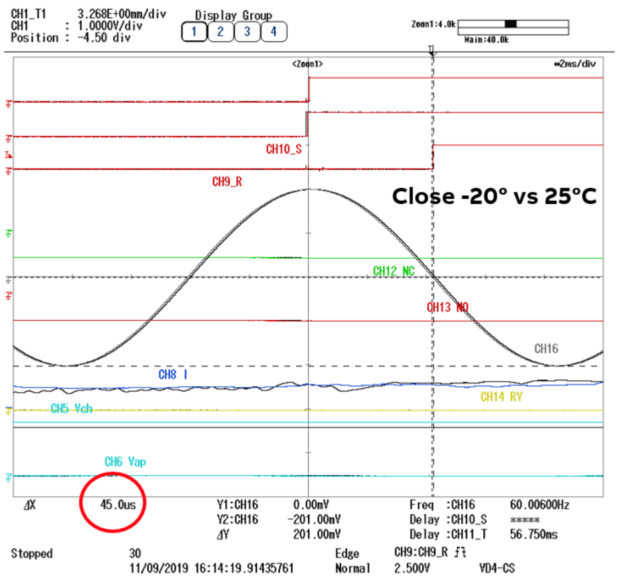


Figure 8: Timing comparison of Close +60°C and -20°C vs +25°C

4 CONCLUSIONS

This paper introduces in nutshell the main feature of a smart apparatus specifically designed for switching capacitive loads.

The technical solution proves to be very consistent with excellent performance in many situations thanks to the use of synchronization feature eliminating the inrush current.

The synchronized openings also guarantee the switching operations without restrikes combined with the ability to interrupt high short circuit current.

The paper also describes that, together with the new approach in design and features, the standard tests need to be integrated with additional pass/fail criteria in order to guarantee the performance of the newly introduced features.

In conclusion, this unique and integrated high performance Circuit Breaker is the perfect solution for highly demanding capacitive current switching applications.

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