

Introduction: short history of controlled switching

Following introduction of electronic based protection devices, early 90's has seen introduction of first controlled switching devices, so called "zero crossing devices", with extremely basic functionalities. During 2000's, with progresses of real time and embedded processing power, CSD functions have been largely improved (transient records, line and power transformer residual flux function). Nowadays, state of the art electronic technologies allows construction of extremely accurate devices, able to store the full-service life of a circuit breaker, which facilitates availability and post processing of relevant performance indicators:

- Making times from voltages (downstream or upstream) or currents
- Reignitions
- Inrush currents
- Voltage dips

It is emphasized the necessity to connect 6x AC voltages for best performances.

Controlled switching is not a technology easy to understand, but years after years, pedagogy (papers, REX, efforts of manufacturers) helps customer acceptance. Historically, the concepts behind controlled switching, and the way to implement it, were probably not explained very well.

Value chain, keys for successful installations

Technology itself is not expensive (standard electronics) but development of a CSD represents an enormous effort of R&D and industrialization.

Commissioning is the key to successful installation. A typical commissioning procedure (including dry tests and live tests) cannot reasonably last below 2~3 days.

Proper controlled switching commissioning requires knowledge in various disciplines:

- Circuit breakers
- High voltage networks, and network transient origins
- Low voltage techniques and cabling
- Computer engineering

Scope of responsibility

It is emphasized the interest of a CSD + CB as an infrangible device, from the same manufacturer. Indeed, who to blame in case of disappointing performances? It is reminded that no standard exists for controlled switching devices (this is a rather severe limitation to the spreading of such a technology)

Reliability

Reliability is not a concern. Standard MTBF calculation procedures (MIL-HDBK-217F, FIDES...) often lead to much more severe results than reality. Regarding other commercial activities (protection devices), for which annual quantities are much higher (installed base is much larger), some companies are switching to MTBF figures based on REX. As protection devices and CSD are based on same technology, it can be aligned.

IEC 61850

Although most controlled switching applications are standalone, there is a trend to connect the CSD via 61850 MMS. In addition to higher-level connection, replacing conventional CT/VTs with sampled digital values was experimented with pilots. This principle will be deployed in the field to support the implementation of the digital substation.

Applications

Controlled switching is virtually applicable to any kind of load, but four kinds of loads are traditionally managed. For some of them, alternatives exist.

<i>Application</i>	<i>Mitigation of switching detrimental issues</i>
Power transformers	CSD
Shunt reactors	CSD or Surge Arresters (SA)
Line / cables (no autoreclose with cables)	CSD or Pre-Insertion Resistor (PIR)
Capacitor banks	CSD (PIR ?)

Shunt reactor

Shunt reactor de-energization (arcing time control) is one of the two critical applications for which circuit breaker reliability is a concern. Indeed, repetitive reignitions may lead to rapid circuit breaker failure (accelerated wear of inner insulating parts). It is worth to note that IEC 62271-110 test does not guarantee against circuit breaker failure. It was also noted at many customer installations that field conditions are more severe than -110 test conditions. Surge arresters may be an alternative, but it is emphasized the need to accurately monitor reignitions occurrence. This kind of monitoring is supported by modern CSD, and different alarms can be implemented, as well as reignitions counter.

<i>Alarm name</i>	<i>Explanation</i>
Reignition last opening	A reignition occurred during last opening operation. Reignitions are detected when arcing time is extended by half a period.
Reignition rate	The number of reignitions among N operations exceed a settable threshold. During circuit breaker service life, sparse reignitions may occur. It becomes a concern when it is too frequent.
Reignition max. cumulated	The total number of reignitions exceeds a settable threshold.
Arcing time	The arcing time during last opening operation is above a settable threshold, typically one full period. This is a critical alarm, indicating that the circuit breaker is near from failure to interrupt.

It is also worth to mention that shunt reactor energization is not critical (for some installations, closing is not controlled). In any case, transient current cannot exceed 2pu ("DC component", without any current zero missing concern). Protection system, if correctly set, should not trip in case of worst condition.

Power transformer

Power transformer energization is an application for which no alternative to controlled switching exists. Despite some literature stating that PIR may be an alternative, it has been proven that PIR has very limited efficiency regarding excessive magnetizing inrush current, even when asking for long insertion time (the saturation phenomena lasts much longer than any feasible insertion time).

For illustration, an example of enormous (>8.7kA) inrush current was recorded in 2017 with a circuit breaker fitted with PIR. Subsequently, the controlled switching technology was sole able to control the inrush currents with this installation.

The concern with power transformers energization (power quality) becoming worse, some countries or utilities enforce more severe requirements (max voltage dip, Brazil requires CSD on each CB...).

Conclusion

Controlled switching technology is more and more trusted and mature. Evidence of benefits is now well proven, and manufacturers have made efforts toward simplicity and pedagogy.

In many cases, it is the unique way to maintain switching transients at an acceptable level, or to preserve the circuit breaker from accelerated ageing.

Without speaking of the records and measurement accuracy, which bring a lot of useful information about the actual site conditions of the circuit breakers. It is now possible to compare field records with power laboratories records (type tests).

CSD market is continuously rising.

However, there is several remaining concerns:

- Quality of commissioning: the few experts cannot attend every installation in the world (they often support remotely). Thus, training of specialists is essential.
- At customer side, the persons in charge of controlled switching maintenance/follow-up are often not well identified (maintenance department? protection and control department?)
- No standard (similarly as ANSI codes for protection devices)
- IEC61869 not finalized