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GROUP REF. : A3
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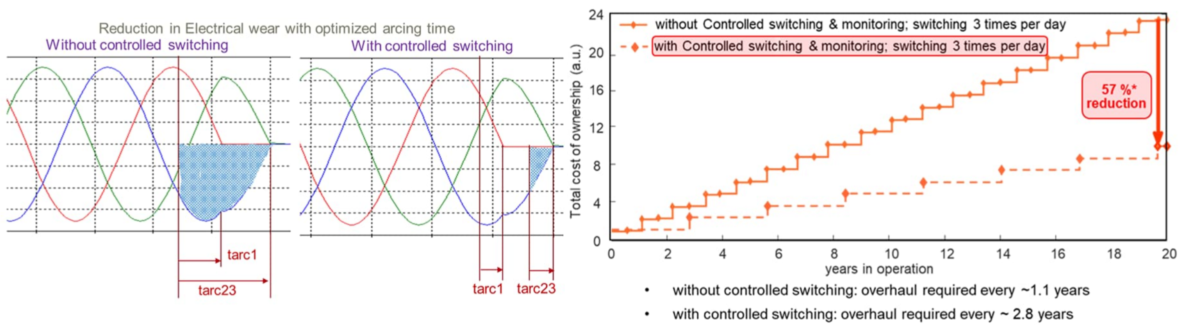
The special reporter asks that “Controlled switching technology, known for about thirty years, seems to experience a renewed interest and applied more and more frequently. What is the reason for that? Higher reliability, more trust in this technology, possibility to be integrated in IEC 61850 digital substations?”

Controlled switching has been successfully used for mitigation of switching transients since more than three decades now. Moreover, it is getting renewed interest due to getting remarkable results for handling power system related issues like improvement in grid reliability during switching events for various power system equipment, managing reactive power requirements of weak grids during transient state.

Another reason is its emerging applications for managing switching transients for power equipment connected to renewable and industrial plants. The controlled switching also offers optimum asset utilization together with life cycle management of various power equipment and various switchgear component most importantly, the circuit breakers. With reduction in switching transients, it assists in reducing failure rates of these equipment. By reducing wear & tear of circuit breaker internal components, it helps in optimizing maintenance requirements for circuit breakers connected to the capacitor banks, reactors and power plants. The advantage gained depends upon CB characteristics, its frequency of operation and load application. Hence, the gain needs to be evaluated on specific case basis. One of such examples is shown in Figure 1 for a CB used in a power plant. The figures are indicative and shown only for explanation purpose.



**Figures are indicative for demonstration purpose and need to be evaluated on case-to-case bases*

Figure 1: Optimization of maintenance requirements for a circuit breaker in power plant

Furthermore, latest generation of controlled switching devices being numerical IED type, are employed with advanced digital algorithms for switching and monitoring. Thereby, they offer repeatable mitigation performance and accurate monitoring of the switching performance together with circuit breaker monitoring. Also, these devices can acquire samples from NCITs as well as from MUs and can communicate on IEC 61850. Lastly, capability for integration with SCADA together with abovementioned features, makes them well suited for the concept of “Digital substations” like other numerical IEDs. The example of installation of a CSD in an IEC 61850 based digital substation is shown in Figure2. The entire substation has only electronic instrument transformers (EITs), which transmit digital sampled voltage and current values to the receivers including CSDs.

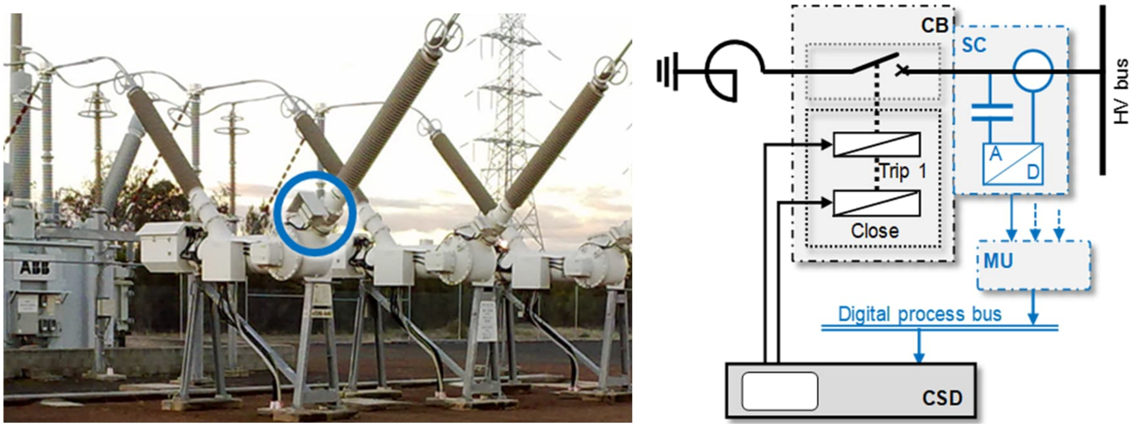
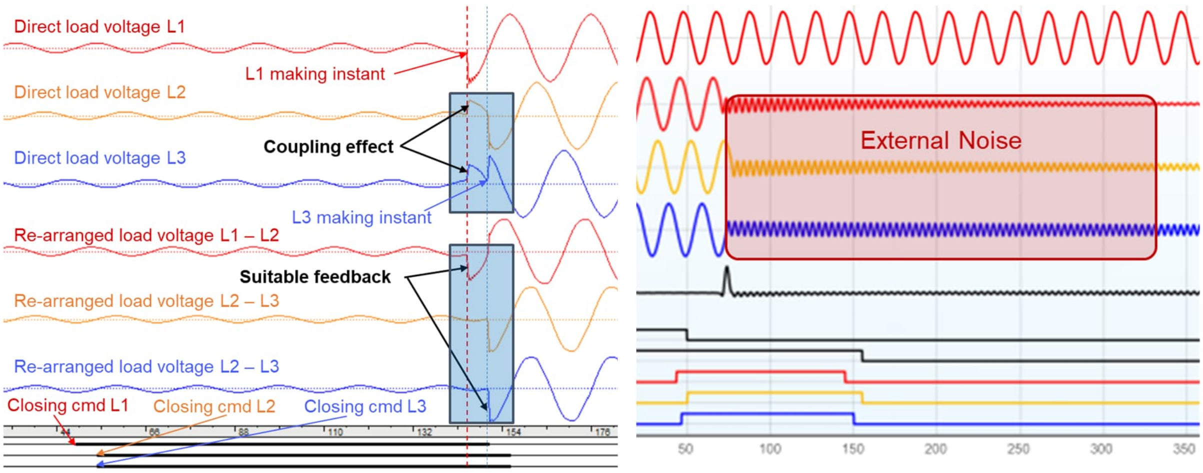


Figure 2: Outdoor hybrid switchgear (MTS having spring-hydraulic drives) with redundant EITs and IEC 61850-9-2(LE) process bus for sampled values (blue). SC = Secondary Converter (on CB pole), MU = Merging Unit (in control house, same as CSD).

The advantage of advanced numerical algorithms for accurate detection of switching instant and monitoring the performance of controlled switching is presented in Figure 3.
It shows effect of interphase coupling during energization of a power transformer from having either a delta connected winding and/or 3-limb core design, when being energized from the grounded star type winding. The common start of transformer side voltages for three poles makes them unsuitable for switching instant detection for individual poles of circuit breaker. Using digital signal processing available with latest generation of numerical relays, the voltages can be differentially arranged and thereby can be made suitable for switching instant detection as shown in Figure 3. The figure also presents effective use of digital filtering to eliminate effect of external noise obtained post current interruption for a shunt reactor application when current is being measured through busing CT of the reactor located after the circuit breaker, towards the reactor side. This is observed due to energy oscillations between stray capacitance and reactor inductance, which otherwise, can result into incorrect current interruption detection and hence, false re-ignitions.



Re-arranged load voltages to remove interphase coupling effect for using feedback during transformer energization *Removing external noise in current waveform with digital filtering to use as feedback during reactor de-energization*

Figure 3: Special arrangement of transformer side voltages and elimination of noise during reactor de-energization for switching instant detection

Figure 4 shows emerging application of controlled energization of a compensated cable to mitigate switching overvoltage. This application is used very frequently in offshore wind farms and oil platforms. For cables having shunt compensation higher than 50%, applying purely capacitive switching targets to mitigate switching overvoltage, would result into prolonged (can be more than 20 cycles for very high compensation) missing zero phenomenon on charging currents. In event of protection mal operation, this would result into current interruption being delayed by a number of cycles and hence, arcing between the contacts for such a long duration. This may increase the risk of potential damage to the circuit breaker. By shifting the target, little away from the purely capacitive target will avoid the missing zero phenomenon and moderate mitigation of the switching overvoltage on the cable. In such cases, optimum switching strategy shall be derived using network study and considering technical specifications of the cable.

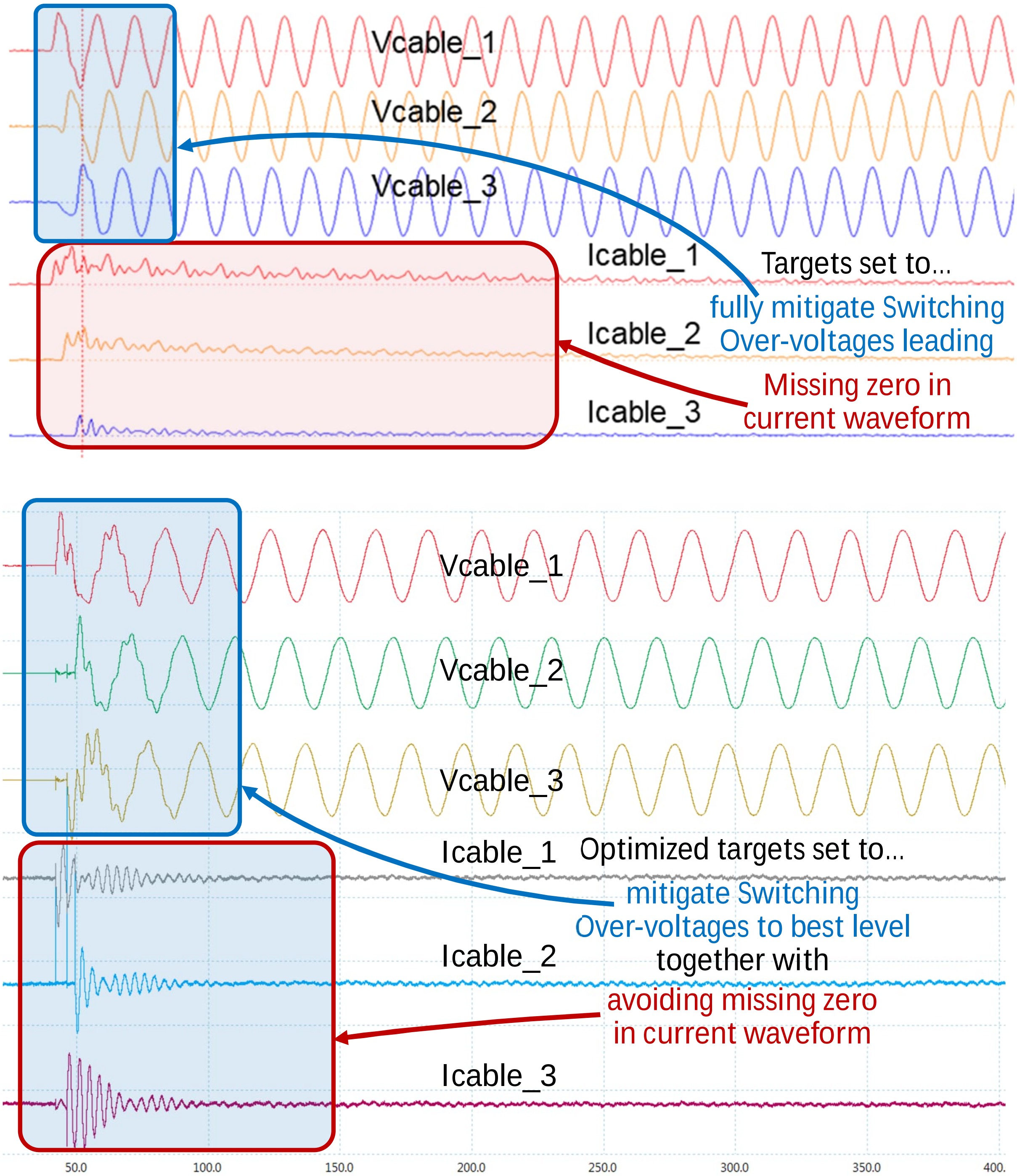


Figure 4: Controlled energization of shunt compensated cable with purely capacitive target (top figure) versus optimized targets to avoid missing zero phenomenon