

## CIRCUIT-BREAKER RMU IMPROVES MV/LV TRANSFORMER PROTECTION

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### ABSTRACT

*Traditionally MV/LV transformers have been protected by switch-fuses because of the significant cost differential with respect to withdrawable CBs and relays.*

*The main advantage for using RMU with fixed integral low cost CB is that it allows to have an improved transformer protection at an equivalent lifetime cost, thus making transformer CB protection affordable. Today, over 60% of the SF6 RMUs sold by the author's company use CB function.*

### INTRODUCTION

Public distribution networks as well as industrial MV networks usually include Ring Main Units (RMUs) in MV/LV substations [Figure 1].

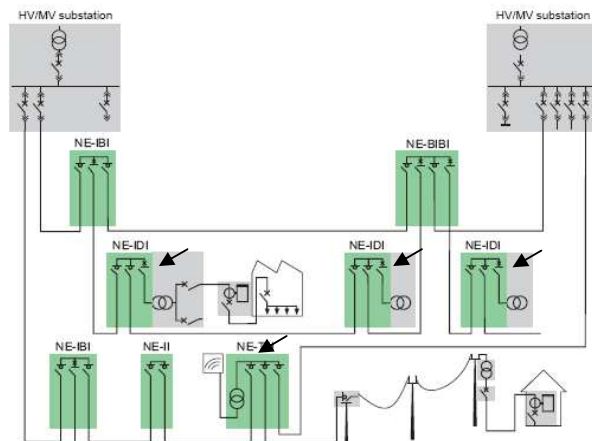


Figure 1: position of transformer's protection

In these substations, MV/LV Power transformers supply energy to private customers, buildings or industrial plants. In the past, the most popular scheme to protect these transformers was the MV switch-fuse combination. This solution was simple and cost-effective.

On the other hand, circuit-breakers were expensive and adapted to HV/MV substations but not to MV/LV substations. Electromechanical protective relays as well as the first electronic generation relays needed an auxiliary DC power supply to operate and had a significant burden. This required high burden CTs which were very bulky. The cost and size of these equipment prevented the general use of circuit-breakers to protect transformers in MV/LV substations.

Over the past 15 years, switchgear manufacturers have designed circuit breaker units inside compact SF6 insulated RMUs [Figure 2], self powered relays and optimized CTs with an equivalent lifetime cost level to MV switch-fuse solution.



Figure 2: RM6 and Ringmaster SF6 RMUs with integral circuit breaker and self powered relays.

Electrical utilities in countries such as UK, Russia, Thailand, Saudi-Arabia, Vietnam and India have already changed their policy to adopt CB protection for MV/LV transformer. The trend is now clearly moving from traditional MV switch-fuse to circuit-breaker [Figure 3].

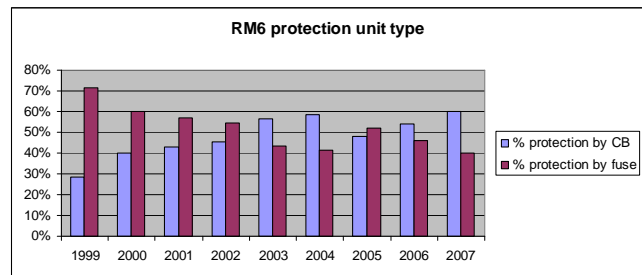


Figure 3: Schneider Electric SF6 RMU sales evolution (CB versus switch-fuse version)

Among the factors that has made utilities and private customers choose circuit-breaker solution is the need to improve the quality of service while at the same time optimising all their investment. The circuit-breaker with self-powered protection relay is easier to set than MV fuse and facilitates coordination with upstream and downstream protections.

**MAINTENANCE ISSUES**

Circuit-breakers require less maintenance than MV switch-fuses and reduce life time cost because:

- there is no need to keep large stock of spare fuses,
- when a single fuse blows it is also necessary to replace the two healthy ones, because they may be damaged by the fault current.

There is also a risk to use inadequate fuses, when making a replacement, including:

- replacing fuses with a lower rating, which may lead to overheating of the fuse.
- using fuses other than those recommended by the manufacturer, which may cause overheating and damages. This practice is not compliant with IEC standard 62271-105 [5] that considers a fuse as an “original” spare part.

The replacement of the fuses is becoming a common operation in heavily loaded electrical networks. As utility networks are privatised, there is an incentive to make full use of installed capacity. As a result MV/LV transformers are used closer to their overload capacity. Electronic relays provide a a good overload protection and are easy to set, while fuses can’t provide any overload protection (See IEC/TR 60787 § 6.3.2) [4].

Modern protective relays are now almost maintenance free, as they include self testing features. Moreover, it is easy to check the protection chain at commissioning stage with simple testing devices.

**PROTECTION PERFORMANCE**

Compared to MV fuses, circuit breakers combined with electronic protection relays bring many protection selectivity improvements, including:

- coordination with upstream and downstream devices;
- discrimination of inrush currents;
- detection of low level phase and earth fault currents.

**Protection coordination**

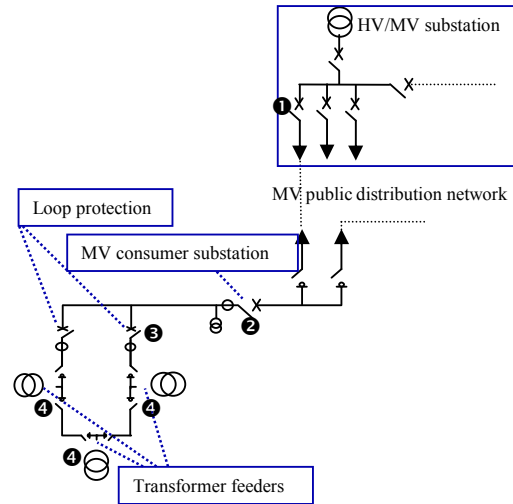
The MV/LV distribution transformer protection needs to detect faults not only in the transformer itself, but also in the LV zone up to the first LV protection device. It must also discriminate with devices upstream and downstream, a detail often overlooked.

**Coordination with upstream protection**

In all cases, circuit breakers with overcurrent and earth fault relays are used for the upstream protection levels,(e.g. primary substation feeder).

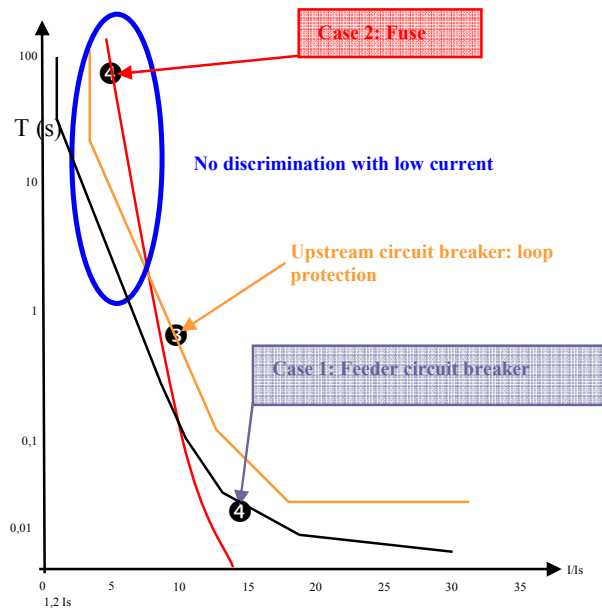
The MV/LV transformer protection device must therefore be coordinated with the upstream relays. In case of MV fuses, coordination is at best a compromise because of fuse’s steep time-current characteristic.

MV networks for large MV customers [Figure 4] [1] often require protection discrimination up to six levels including 4 MV stages and 2 LV stages.



**Figure 4:** stages of protection

Figure 5 shows that in the case in which a circuit breaker is used for MV/LV transformer protection, the curves are correctly coordinated. However, in the case of an MV fuse, the protection curve intersects the curve of the upstream circuit breaker. At low fault level the most likely situation in practice, there will be no discrimination, which could bring a whole industrial complex to a standstill.



**Figure 5:** Phase protection tripping curve

### Discrimination with LV installation

In cases where the LV installation includes an incoming LV ACB, discrimination with the MV fuse curve becomes difficult. In the case of MV circuit-breaker, it is possible to choose the right curve in the electronic relay to ensure discrimination between MV and LV protection.

### Inrush current

Transformer energizing produces very high transient inrush current that can reach peak values, up to ten times the peak rated current. This is natural phenomena and the protection should not operate. To avoid mistrips on inrush current, MV fuses are often overrated [2], [4].

The circuit breaker allows greater flexibility to avoid tripping current where still maintaining a good level of protection due to the electronic relay time/current characteristic.

### Low magnitude phase fault current

MV/LV transformer has usually a very low failure rate. Faults are interturn faults or earth-phase faults and are located inside the primary or secondary windings or on the LV zone. Phase-to-phase faults between MV bushing are of more seldom occurrences [Figure 6].

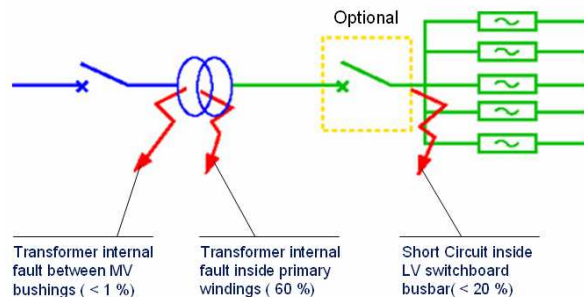


Figure 6: localization of a fault

Most common faults are short-circuit inside a turn of the MV winding where the fault level is of low magnitude (1 to 6 times the rated current).

In case of circuit-breaker, as soon as the fault reaches the setting, the relay will detect it and trip safely the circuit-breaker, disconnecting the MV/LV transformer circuit.

In case of MV fuses, it is possible that such a low fault level could be under the minimum fuse interrupting current ( $I_3$ ) causing the fault to evolve and generate more damage than necessary.

The MV fault current ( $3 I_n$ ) may also be low magnitude due to a fault in the LV side of the transformer. This will remain undetected by an MV fuse.

### High magnitude fault currents

In the rare event of a short-circuit between MV bushings,

the protection must act quickly. In that case the circuit-breaker is slower than the MV fuse that has current limiting capabilities [6]. However, the circuit-breaker will clear the fault in less than 100ms, and this is effective enough to avoid any damage. Some high magnitude fault currents are first low magnitude fault currents that evolve because uncleared by fuses. In these cases, circuit-breakers will clear them before they become of high magnitude.

### Low level MV earth-faults

In case of high impedance earth fault on MV winding or solid earth-faults in impedance earthed neutral, the earth-fault magnitude is below the rated current of transformer. Modern self powered relays also integrate sensitive earth-fault protection and then provide effective coverage on these conditions.

It is now possible to wake-up a self powered protection relay with a low load current ( $< 5 A$ ) at which point the sensitive earth-fault protection becomes operational.

### HARSH CLIMATE WITHSTAND

MV/LV substations are often installed in places with high level of humidity and pollution. Fuses are weak into harsh environment because they need to be isolated in air and the electric field on fuse holder may result in partial discharges. MV fuses are installed in a confined environment and care must be taken on the RMU architecture and the fuse choice to avoid overheating.

The circuit-breakers in SF<sub>6</sub> RMUs are inside the SF<sub>6</sub> tank and are inherently unaffected by environmental conditions.

Circuit-breakers with self powered relays and integral CTs constitute a robust protection chain with an equivalent MTBF figure as MV fuses [3].

### TECHNOLOGY EVOLUTION

#### SF<sub>6</sub> RMU technology

Schneider Electric was one of the first manufacturers to introduce 3 position SF<sub>6</sub> circuit-breaker using self expansion and rotating arc technology. Today many manufacturers are able to propose cost effective RMU with circuit-breaker function for transformer protection.

#### Self powered relay technology evolution

The first generation of self powered electronic relays was developed in the late 80's for French and Italian national utilities EDF and ENEL. Based on analogue electronics, they were mainly used for protection of large MV consumer installations, without the need of an auxiliary DC supply, thus improving reliability [Figure 7].



**Figure 7:** Statimax self powered analogue relay

The first self powered relays designed for MV/LV transformer protection were introduced in the early 90's. They were microprocessor based and included overcurrent and earth-fault functions with standard IDMT curves [Figures 8 and 9]. Optimized CTs and trip coils enabled to create a robust protection chain with simplified settings and optimized cost.



**Figure 8 :** VIP 30 self powered relay for basic transformer protection



**Figure 9 :** VIP 300 self powered IDMT overcurrent and earth-fault relay

## CONCLUSION

Modern SF6 RMUs with circuit-breakers and integral self powered electronic relays provide a superior protection to MV/LV transformers at equivalent lifetime cost than traditional MV switch-fuse solution.

The main advantages of CB solution are:

- better discrimination with other MV and LV protection devices;
- improved protection performance for inrush current, overloads, low magnitude phase-faults and earth-faults
- greater harsh climate withstand;
- reduced maintenance and spare parts.

Utilities and private customers all over the world have quickly understood the advantages of CB RMU and self powered relay for protection of MV/LV transformers. This is reflected in the increased uptake of CB RMU, which now accounts for 60% of RMUs sold.

## REFERENCES:

- [1] Juan Tobias, "Are you properly protected?" in Electrical Review Vol 225 No 23 27 November - 10 December 1992.
- [2] Didier Fulchiron, "Protection of MV/LV substation transformers", Cahier Technique no 192, 01 July 1998.
- [3] Gerard Schoonenberg, Jan Stoelhorst, Alex Pikkert, "Protection designs in medium voltage distribution networks, time to reconsider" in Proceeding CIRED conference Turin 2005.
- [4] IEC IEC-60787 "Application guide for the selection of high-voltage current-limiting fuse-links for transformer circuits" 2007-03.
- [5] IEC-62271-105 "High-voltage switchgear and controlgear - Alternating current switch-fuse combinations" 2002-08
- [6] IEC-60282-1 : High voltage fuses. Current limiting fuses 2005-11.