# EFFECTS OF LOCAL INTERPRETATIONS OF OPERATIONAL SAFETY IN NORTH AMERICA AND EUROPE ON DESIGN OF MEDIUM VOLTAGE SWITCHGEAR

Paul SCHOTEN
Eaton – The Netherlands
PaulSchoten@Eaton.com

Phil DINGLE
Eaton – United Kingdom
PhilipJDingle@Eaton.com

Walter KAMINSKYJ
Eaton - Canada
WalterKaminskyj@Eaton.com

## *ABSTRACT*

*This paper discusses various existing interpretations of safety in the operation of Medium Voltage switchgear by users throughout North America and Europe as encountered by manufacturer Eaton Holec. It explains how these procedures result in a range of customer specific requirements regarding several – notably mechanical – features of the switchgear. Finally this paper points out the potential benefits that Eaton Holec sees in further standardization of the many local variants of safety regulations that exist at present, and suggests ways to attain a higher level of internationally and intra-company accepted safety standards*

## INTRODUCTION

For decades Dutch switchgear manufacturer Holec - now Eaton Holec – has developed, manufactured and delivered an ever growing program of Medium Voltage (MV) systems for its customers. In the early years these customers were found mostly in The Netherlands but after the 1970's an increasing number were from other European countries, the Middle East, Africa, Australia and Asia. More recently, in 2004, the United States of America and Canada were added to this broad market when Holec was acquired by the American company – Eaton. For Eaton Holec this gradual market expansion has been accompanied by a steady growth in the number of customer-specific features, despite the fact that the systems of Eaton Holec are designed expressly to comply with 'generally acceptable' safety practices in their standard version as much as possible. It seems there are still many local interpretations of the concept of operational safety for MV switchgear.

This paper intends to demonstrate that although the IEC is gaining increasing worldwide acceptance in its objective to promote international co-operation on all questions concerning standardization, a significant variety of additional national and local regulations remain that influence the operational procedures of individual electrical companies, and the corresponding specific characteristics of the MV switchgear. And although this may be justifiable from the individual customers' point of view, it is argued in this paper that further standardization of these many local variants of safety rules would be beneficial for all parties involved.

## SAFETY PHILOSOPHIES PER COUNTRY

This chapter presents the outlines of safety philosophies that apply in different countries for which Eaton Holec develops MV-switchgear, and shows examples of how these views result in specific requirements regarding the design of the equipment with respect to:

1. arc flash hazards
2. operation and maintenance

Both principal differences between ANSI and IEC standards on which switchgear design in respectively North America and Europe is based, as well as a number of remarkable specific differences found in IEC switchgear in various European countries are discussed.

## Canada and United States of America

### General

The safety of personal working with and in the vicinity of electrical equipment is not subject to compromise. The cost of compromising safety is huge when human life is at stake without even taking into account the legal liabilities especially in today's litigious climate. Since the failure of electrical equipment can to some degree be considered a random event, different strategies have evolved to protect personal from injury when working with energized electrical equipment. The strategy has to take into account the cost of safety.

### Arc Flash Hazards

An arc flash event releases a tremendous amount of energy in the form of thermal heat, toxic fumes, pressure waves, blinding light, sound waves and explosions that can result in serious injury including critical burns, collapsed lungs, loss of vision, ruptured eardrums, puncture wounds and even death.

Prior to the mid 1990's, there were minimal guidelines that covered employee safe working practices around electrical distribution equipment. In the USA, NFPA created an employee safety document, NFPA 70E that set the standard for electrical safety in the workplace. In Canada this document is referenced as CSA Standard Z462.

NFPA 70E established a flash protection boundary, recognized the arc flash hazard, required employee protection from the flash hazard, the use of personal protective equipment (PPE), fig. 1, and requirements for an energized electrical work. The intent of NFPA 70E regarding arc flash is to provide guidelines that will limit injury to the onset of second-degree burns. How NFPA 70E is implemented will establish the cost of safety. The cost of safety will be determined by the potential magnitude of the arc flash hazard.

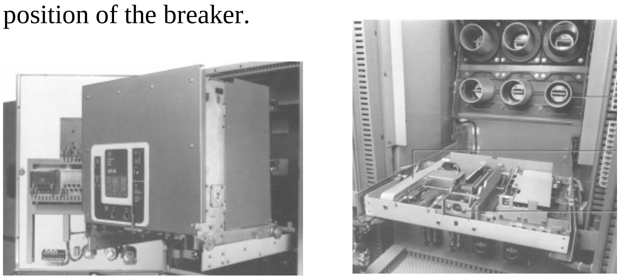

*Fig. 1 Example of Personal Protective Equipment (PPE) to protect against effects of arc flash, as required by NFPA 70E*

An arc flash hazard analysis is critical to the safety of plant personnel working on or near exposed energized electrical equipment. This analysis will quantify the release of thermal energy associated with potential arc flash hazards and will describe safety recommendations such as establishing protection boundaries and specifying the type of PPE.

To calculate the cost of operator safety is not a trivial task. One needs to take into account the cost of using PPE, which may require several people doing a task that would have taken one person previously to do. If using the PPE is impractical to service the equipment then the alternative is to de-energize the equipment. There is also the issue with the equipment itself; how much effort should be expended to re-engineer the equipment or use PPE to operate or service it. The last issue is how to minimize the impact on the bottom line without compromising personal safety.

**Position Indicators and Interlocks**

There are inherent features in ANSI Metal Clad Switchgear that promote safe use and operation. A defining feature of the construction of ANSI Metal Clad Switchgear is that it has been designed to be serviced, specifically the circuit breaker needs to be withdrawable for maintenance work.
The breaker can be located in three distinct positions within the cell: connected, test or disconnect position. By being able to draw out the breaker and locking it in the disconnect position, this provides the operator a positive indication of visual isolation via a mechanical indicator on the cover of the breaker that is directly coupled to the racking mechanism, fig. 2. Limit switches mounted within the breaker cell provide positive electrical indication of the position of the breaker.



a b

*Fig. 2 Withdrawable circuit breaker in disconnect position (a) and removed (b) giving direct visual access to primary contacts of panel, as required by NEC/CEC*

Both mechanical and electrical position indicators provide the engineer the means for designing a robust control scheme that is safe to operate. In a multi-breaker configuration the electrical position indicators can be wired to prevent out of sequence operation without introducing additional points of failure into the system. Having a simpler control scheme allows a quick review of the equipment prior to any operation or maintenance. The simpler control system also provides a quicker understanding of how the equipment is interlocked which increases the degree of safety in operating or maintaining the electrical equipment.

Since the position indicators and electrical interlocks are no optional but standard features, there is no added cost for these safety related features. In fact, there is an intrinsic cost avoidance in the cost of ownership of the electrical equipment.

**Directly visible break in fixed breaker system**

After the integration of Holec and Eaton in 2003, Canadian customers showed interest in the relatively compact IEC-compliant double busbar system MMS. It appeared that although this system was favoured for its benefits - notably a solid and safe 31,5 kA 1s arc resistant design - it would not be acceptable in Canada. The system with its maintenance free fixed mounted breaker did not provide the operator the direct indication of visual isolation as required by the Canadian Electrical Code (CEC), and that can be provided by either withdrawal of the breaker or some other viewing possibility that MMS did not offer. This posed a challenge because the disconnector contacts of MMS are situated in a separate metal enclosed compartment located in the heart of the panel, and therefore are difficult to access from the front if the panel is to remain intact. Research learned that an acceptable visual isolation can be realized by use of a powerful (warm light type) endoscope with a 90° viewing angle. When this endoscope is inserted in the MMS-enclosure via a steel tube with a heat and pressure resistant inner glass tube, it produces a direct and clear image of the position of the disconnector pins inside the closed compartment, fig. 3.

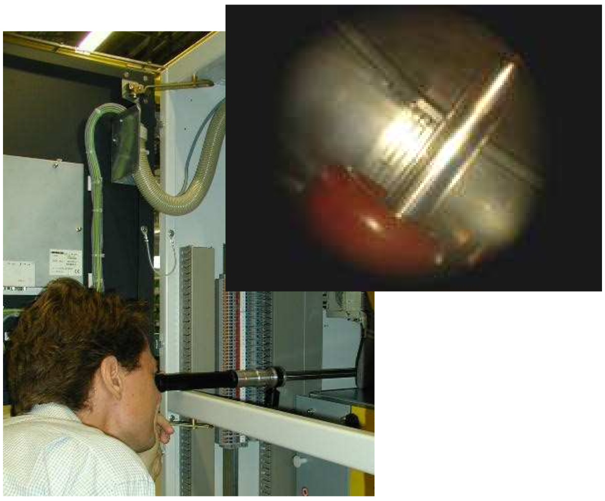


*Fig. 3 Endoscopic inspection of disconnector contacts MMS*

# Europe

## General

MV-switchgear in Europe is generally based on IEC standards. Compared to the ANSI standards of North America IEC regulations are typically more performance and testing oriented, where the ANSI standards are more construction and application oriented. A specific difference to be mentioned in this paper is that ANSI defines metal clad switchgear more extensive, notably including the following features:
1. withdrawable switching devices
2. primary conductors covered
3. more extensive compartmentation

IEC is not based specifically on switchgear that should have a withdrawable breaker for maintenance purposes, and does not require a directly visible break between breaker and main busbar as condition for operational safety. Instead IEC also accepts the use of a positively driven position indicator that is « clear and reliable » and that isolation distances are verified through type testing. Thus a fixed system becomes acceptable and even desired by many utilities as it eliminates a maintenance stage increasing operational hours.

IEC distinguishes the Internal Arc Class (IAC), a classification not defined by ANSI that is intended to offer a tested level of protection by the MV-system against burns to a person standing in the vicinity of equipment in case of an arc fault. IAC is established by a test that demonstrates if an enclosure, in which an arc flash is initiated and sustained for time lengths of typically 0.1, 0,5 or 1 s, remains intact to at least the degree that no textile indicators placed at 30 cm distance from the panel are burned and no fragmentation of the enclosure occurs. This optional IEC rating is increasingly required by customers in Europe.

Furthermore within Europe, to varying degrees, the design objective linked with operational procedures is to eliminate the risk of arc faults occurring under normal operating conditions. A need for protective suits or flash protection boundaries as described in the USA and Canada is not recognized in Europe.

Remote operation of the switchgear is an integral part of most systems, but the integration of the components and local switching practises add further complexity to the basic IEC concept.

## United Kingdom

The specification of MV-switchgear in the United Kingdom is based on IEC-specifications plus additional safety requirements provided by the ENA regarding specific operational and safety practices. The addition results in some significant differences compared to the general situation in continental Europe. Here follow some of these differences and their motivation, as explained in [1].

The Health and Safety legislation in the UK sets out a hierarchy of measures companies are required to follow to improve safety. At the head of this list is the concept of designing out risk. The use of procedures and training is lower down the hierarchy, and should be used when it is not practicable to design out the hazard. This results in notably the following particular differences of UK requirements compared to continental Europe:
1. Cable testing – UK specifications require interlocked test access in order to minimize the risk of test connections becoming energized.
2. Operational padlocking – UK network operators use a common basic system of padlocking to ensure that work on the network can be done safely.
3. LV compartment locks – Open and close switches and MCB’s require to be padlockable, or removable LV fuses are to be provided, in order to conform the LV compartment on MV switchgear to UK practice.
4. When work has to be carried out on a panel, all switching must be made locally either manually or electrically and the operational padlock sequence used. Whilst in principle Health and Safety Guidelines would accept the use of Electronic local operation, compliance with IEC 61508 would first be required.

Fig. 4 shows a typical example of MV switchgear equipped with mechanical features relating to the above mentioned UK safety requirements.


*Fig. 4 Example of MV switchgear installation in UK*

*Fig. 5 Example of MV switchgear installation in Finland*

**Finland**

A number of factors have led the Finnish Utilities to take a different approach to their network structure:

- Fully deregulated Utilities with minimal staff, all new installation or maintenance outsourced
- High levels of compensation for customer hours lost.
- The geography of the country and weather conditions which makes quick and easy access to substations difficult

The combination of these points has led to a major investment in the network infrastructure, resulting in a highly automated system. Health and Safety regulations SFS 6002 (EN50110-1/2 plus national supplements) are applied to the complete system. The emphasis is on continuous operation of the system, supported by SCADA diagnostics. Where local switchgear operation is required, the electronic control systems are used. A high level of operator training is put in place to support this type of approach.

Additionally to ensure the ongoing operational efficiency of the switchgear all internal arc vents are channelled to the outside.

Fig. 5 shows a typical example of a MV station in Finland, clearly lacking many mechanical features compared to fig. 4. It should be noted however that this system does have one padlocking facility behind the door, which is interlocked with a key that gives access to the cable compartment only when the cable is earthed and the earthed position is padlocked.

**Central Europe**

Another example of interpretation of operational safety is found in Central European countries where primarily RMU's are used based on the concept of an SF6 breaker and a separate earthing switch for the cable. To facilitate the operation of a different system concept, with disconnector and a vacuum interruper breaker used also to earth the cable, like Eaton Holec's SVS and Xiria, some customers require an additional function indication window. This indication gives the operator extra confirmation on the operation panel whether closing of the breaker will connect the cable to earth or to the busbar, fig. 6.

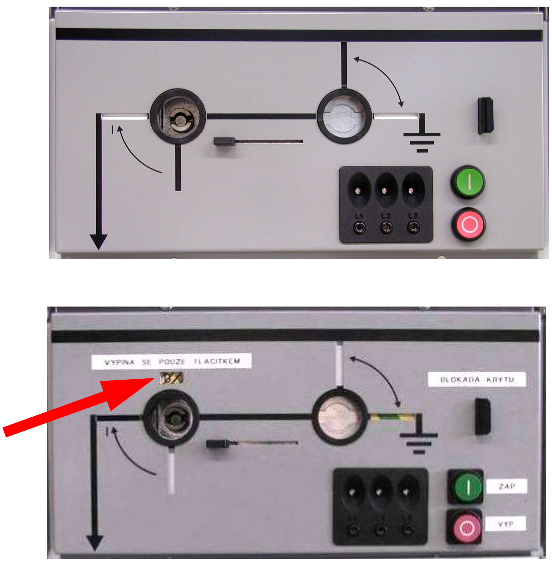


*Fig. 6 Example of SVS MV switchgear without and with additional function indication window for the breaker*

**Sweden**

Notably in Sweden customers have pointed out that the before mentioned function indication of the breaker can cause misinterpretation of the panel reading because this indication shows 'earthing mode' when the disconnector is switched to earthed position. This could be interpreted as the cable being already earthed, which however is only the case after subsequent closing of the breaker. For this reason these customers object to the function indication.

**Belgium**

Belgian distribution companies have very specific requirements regarding the graphic layout (synoptic) of operation panels on MV switchgear, according to specifications of national institute Synergrid that are based on the before mentioned concept of a breaker and separate earthing switch. While the system functionality of SVS remains the same a specific type of function indicator was required and the graphical layout of the position indicators on the operation panel needed to be redesigned structurally to comply with the Belgian regulation, as fig. 7 shows.

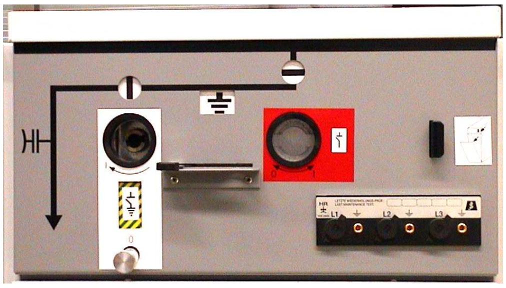


*Fig. 7 Example of SVS MV switchgear with operation panel layout according to regulation Synergrid Belgium*

**The Netherlands**

In The Netherlands, finally, distribution companies tend to accept IEC compliant Eaton Holec systems in their standard version, but here also fundamentally different operational safety systems are used: some companies choose electronically controlled operation and interlocking systems, others require a mechanical system.

## CONCLUSIONS

We have presented a number of variations from European countries and views from North America of operator safety when working with or around electrical equipment. In all cases this is based around IEC or ANSI standards, but with the incorporation of local adaptations. These are largely driven by the country specific Health & Safety guidelines and operational practices, which are further underpinned by the litigious environment end customers face within those countries. We conclude that in the current situation the efforts of switchgear manufacturers and IEC to design out potential risks, strive for uniformity and reduce costs, still are frequently overridden by local needs.

## DISCUSSION

The authors think it is worth discussing the desirability of this situation for the various stakeholders. While everyone will agree that a product should be designed according to highest standards of operational safety, it is also clear that both the end customer and the manufacturer do not benefit from a situation where the precise interpretation of that issue varies widely, because that unavoidably leads to many product versions, higher costs and longer delivery times.

The design of many other industrial products, in particular of the man-machine interface, is nowadays standardized to a higher degree in accordance with internationally accepted safety principles and symbols.

It seems realistic to expect that promotion of more specific design standards for MV switchgear by the IEC will eventually lead to equipment that offers a more uniform level of well defined operational safety against lower costs. Therefore this seems an objective worth to pursue by all parties involved.

## REFERENCES

[1] L. Mackay, 2005, "Switchgear specifications – comparison of European and UK specifications", EDF Energy, London, United Kingdom

[2] B. Bridger, 1997, "Comparison of ANSI/IEEE and IEC Requirements for Metal-Clad Switchgear", *IEEE transactions on industry applications.* vol. 33 no. 1

[3] E-N-S Belgium, 2004, "Specification Technique TST 19-2 – Appareillage MT pour cabines MT/MT et MT/BT"