HARMONIZATION OF SYNOPTIC BLOCK DIAGRAMS ON THE CONTROL PANELS OF MV SWITCHGEAR AND CONTROLGEAR

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SUMMARY

The aim of this article is to make utilities aware of the need for harmonization at a time when more and more manufacturers are bringing MV switchgear and controlgear onto the market and when increasing attention is being centred on the importance of the man-machine interface. It will identify the various stages in the development of this subject, present selected options and give examples of the results obtained for MV switchgear and controlgear from various manufacturers.

INTRODUCTION

Recent years have seen a growing trend on MV distribution networks, and especially in distribution substations, to replace open materiel with MV metal or insulating enclosed equipment. This has led to fewer injuries to workmen, often due to direct contact with active parts, possibly as a result of the lack of automatic locking not technically realisable. The risk of operating errors has not been totally eliminated due to the fact that it is generally due to a human error, and to the lack of convergence of the various synoptic block diagrams designed by the manufacturers. Position indicators combined with synoptic block diagrams replace a direct visual inspection. Consequences of potential operating errors can thus only occur in adjacent stations (essentially by unwanted connections).

This paper studies the main causes of accidents and incidents, the solutions offered by the here above mentioned evolution and the choices that need to be made concerning the man-machine interface in order to maximise positive effects of this evolution.

MAIN CAUSES OF ACCIDENTS

Current situation

Most of the accidents or incidents that occur in distribution substations – whether they result in the accelerated ageing of the equipment, damage to the equipment or, more seriously, personal injury – can generally be attributed to three principal causes :

1. direct contacts with actives parts;

2. failure to check the availability (i.e. not live) of the equipment by means of a reliable system before carrying out the work;

and, most frequently :

3. operator's inadvertence and lack of concentration.

A fourth cause could appear by use of unreliable or unsuitable equipment. This can be avoided by adapting technical specifications to network characteristics and checking the strict conformity of proposed devices. The consequences of any unlikely equipment defects can be further minimised by requiring that the protected equipment be resistant to internal arc faults and ensuring the compatibility between installation and housing.

Conclusion

Since, as we have seen, the causes of accidents or incidents are mainly due to human error, the safest way of reducing the frequency with which they occur is to counter these three main causes and their consequences by harmonising the man-machine interface, harmonization witch facilitates the operator's circumspection.

SUGGESTED SOLUTIONS

1. Protection from direct contact

The first cause may be avoided to a large extent by using metal or insulating enclosed equipment, as is generally the case for new installations today. Adequate locking measures now make it impossible for the operator to reach a live area either voluntarily or accidentally or to work in the vicinity of live parts without a protective screen.

2. Reliable checks on availability

Once we have adopted the concept of protected equipment, the second cause of accidents can be dealt with by equipping the operator with a reliable means of checking whether or not a part is live. The position of the device carrying out the test must be clearly marked so as to avoid any errors of interpretation (see also "definition of the typical synoptic block diagram").
This condition is met if the manufacturer is required to fit in a "VDS"-type interface (Voltage Detecting System), in accordance with one of the options of IEC standard 61243-5, clearly specifying the voltage range in which the system should operate and compatible with the corresponding detection equipment (e.g. 10.0-16.0 kV to cover all voltages between these two values).
The operator's detection equipment must be checked regularly and must comply with this same standard following the same option (high or low impedance).
This also makes it possible to comply with the safety rules set out in standard EN 50110-1, and therefore to run a reliable check on the absence of voltage before earthing. This also avoids reducing the service life of the earthing switch which can close 1, 2 or 5 times on making current, depending on the class of equipment.

3. Harmonization of the man-machine interface

With open equipment, the inadvertence of the field operator could led to physical consequences on the author of the error, within the substation self.

With enclosed equipment, the field operator is well protected and so, inside the substation, any mistakes only result in accelerated equipment ageing (e.g. caused by closing on a short-circuit). Consequences of an incorrect operation on field operators working in a neighbouring substation or on the section of the network between two substations still exist.

If the field operator is working on installations where interfaces can strongly differ from others, depending on the manufacturer, and if he doesn't frequently operate any inadvertence can result in an operation error. The diversity of installations on the network has become unavoidable by the liberalisation of market. This situation leads inevitably to an increasing number of different presentation on the local command boards.

Finding a solution : in view of the major discrepancies noted between the synoptic block diagrams on the control panels of equipment from different manufacturers, we have attempted to clarify and harmonise the situation. We worked closely with the various parties concerned (technical experts, safety officers and field operators) and enlisted the help of an ergonomics consultant in order to determine the optimal type of diagram. After a series of meetings in our training centres examining the various types of equipment used on the Belgian network, coupled with visits to substations including a large numbers of cells, the working group was made fully aware of the difficulties encountered by field operators having to interpret a multitude of synoptic block diagrams presentations.

These meetings identified the plus points of existing diagrams. The result was a typical structure for a synoptic block diagram which all field operators could agree upon and allowing for a common and univocal interpretation of all MV distribution network equipment. This approach does not question the quality of synoptic block diagram taken individually, but well the diversity among them.

DEFINITION OF THE TYPICAL SYNOPTIC BLOCK DIAGRAM

Preconditions

The principles have to be adaptable to most of the existing equipment, the aim being to not have to wait for a new generation of technology and to avoid increasing the cost of equipment.

The main principles must be easily translated into technical requirements that manufacturers offering equipment on the Belgian market should be made to comply with. A deadline should be set for conformity with these requirements.

The other Belgian distributors have been involved in this process from the outset, thus ensuring the harmonization of supplies to the Belgian market which in turn simplifies the task of manufacturers.

Block diagrams - technical requirements

Area of application: the general rules apply to metal or insulating enclosed switchgear and controlgear which do not allow for a clear and unobstructed view of the equipment and a direct and unambiguous indication of its position (open, closed, earthed, test, etc.).
However, the points regarding control mechanisms 11 to 14 are applicable to all enclosed equipment.

Block diagram : the representation of the block diagram must be simple and logical so that there can only be one possible, clear and immediate interpretation. The text on the diagram must be kept to a strict minimum (see point 9: cable direction, type and diameter).

1. The block diagram shall be affixed to the front panel of the cells, on a part that cannot be removed without special tools.

2. The main busbar must be represented by an unbroken horizontal line on top of the diagram affixed to the front panel.

3. On each cell a vertical line (busbar branch) branches off the main busbar line. These lines should be marked with the position indicators of the switchgears. Depending on the physical location of the switchgear and controlgear inside the envelop, it is not always possible to pass a single vertical line through the position indicators concerned. The diagram must nevertheless be drawn in the simplest and clearest manner.

4. The position indicators of the switchgear and controlgear must be representative of their physical position. They should either show an unbroken line (device closed) or a broken line (device open) on the diagram.

5. The lines of the block diagram must be starkly contrasted against the background colour. The difference in reflective power (as a percentage of the incident light radiation) between the lines on the diagram and the background colour must be at least 65%. (For information, this difference is achieved with white or aluminium tones against black, dark blue, crimson, slate grey, dark brown, etc.).

6. The colour used for the lines on the diagram and for the position indicators must not be used for anything else. Similar shades cannot be used on the surface of the diagram (the cells cannot be separated by lines of the same shade of colour). Red, green and yellow may not be used for the single-wire diagram.

7. Lines must be no thinner than 3 mm. The widths of all lines representing power circuits are identical.

8. Any lines that have no meaning for the diagram and all unnecessary text on the surface of the diagram must be eliminated towards easy reading.

9. The voltage detection interfaces should be represented on the diagram by the symbol for a capacitieve outlet. This symbol should also be placed adjacent to the actual interface in case the latter is not in the immediate vicinity (preferably level with the location of the detector).

10. For cable cell, the symbol used to represent the terminal box is a shaded, inverted triangle in the same colour as the line of the MV power circuit. In this case, a free space, bearing no inscription, must be in the immediate vicinity of (and preferably below) the symbol for the connecting cable terminal box. This empty space (in the diagram background colour) should be at least 40 mm high and 150 mm wide. It will contain the information regarding cable direction, type and diameter.

11. It shall be positioned on a part that cannot be removed without special tools.

12. The controls must be conspicuous thanks to the colour of their background area (green and yellow striped for earthing devices, red for switches, disconnectors and circuit-breakers) which we will call “control areas”. These control areas must be located as close as possible to the position indicators for the devices controlled. If the relationship between the control and the position indicator is not clear from the diagram, a dotted line shall run from the control area to the position indicator concerned.

Note that the choice of colours is taking into account their meaning in international standards.

13. These control areas also contain a box displaying the symbol of the device controlled (in accordance with IEC standard 617) in black against a white background or vice versa. These boxes are not framed (to avoid a lack of clarity resulting from too many lines).

14. These control areas must be positioned on the diagram in such a way that it is impossible to mistake the controls and indications they contain with those of neighbouring cells. To this end, for the equipment that is not part of cubical switchgear or controlgear (within the meaning of the Belgian standard NBN EN 298), the cells may be separated if necessary by a wide unbroken line in a different colour from the colours used on the diagram.

15. Motorised controls are shown on a control area (identical to that for manual controls) which also features the motorisation symbol (in line with IEC 617) and identifying the device controlled. The device information is repeated at the device position indicator on the diagram to avoid any possible confusion. The motorisation symbol must also be indicated on the diagram.

A block diagram taking into account all the above mentioned rules is shown below.
Manufacturers have been invited to submit their suggested diagrams to Electrabel in order to avoid any misinterpretation of the specifications.

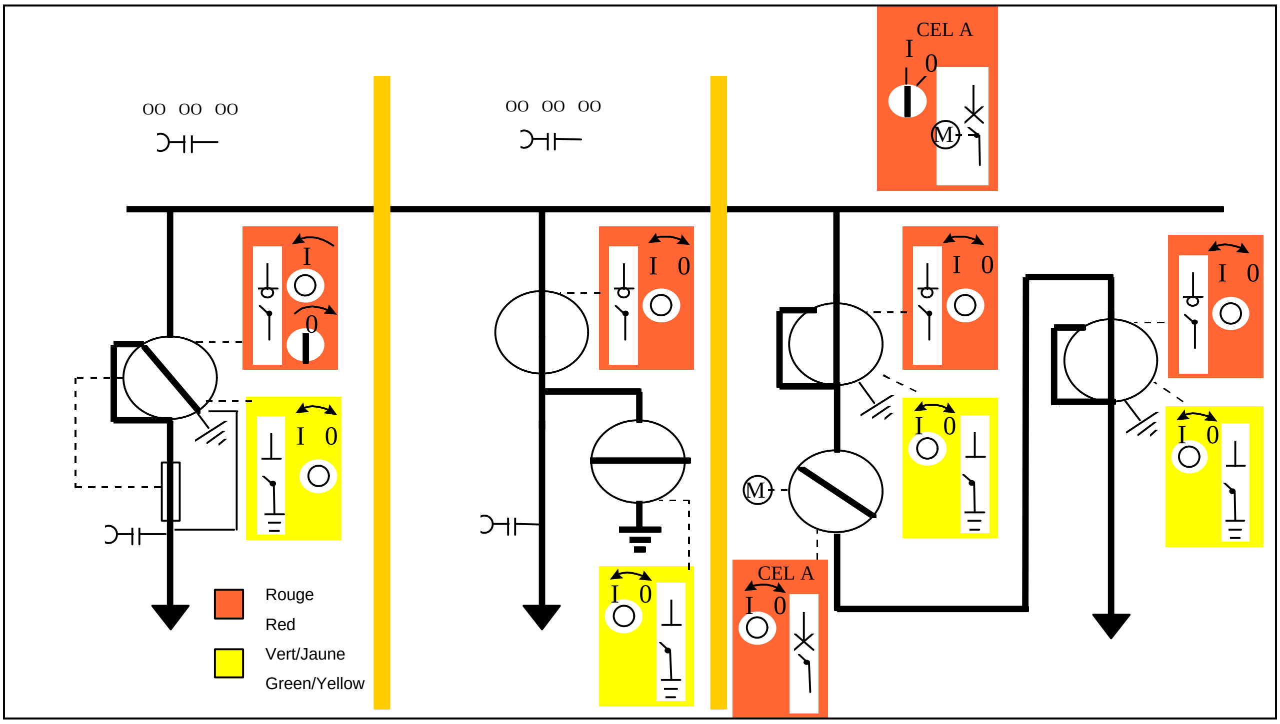

FIGURE 1 - Example of synoptic block diagram

CONCLUSION

We feel that observing these rules may improve the safety of all those who will wish to take them into account, and may amount to some harmonization of enclosed switchgear and controlgear presentation on an European level. This would in turn reduce equipment costs.

The Belgian market is a very open one, and the leading international manufacturers have already taken steps in order to adapt their equipment and bring it into line with our specifications.

EXAMPLES

Here are a few examples of new or adapted installations resulting from close co-operation between Electrabel and the various manufacturers active on the Belgian market:

FIGURE 2 - Application of synoptic block diagram

FIGURE 3 - Application of synoptic block diagram

REFERENCES

[1] CEI 60073 : CEI, Basic and safety principles for man - machine interface, marking and identification.. Coding principles for indication devices and actuators (1996).

[2] CEI 60417-1 et -2 : CEI, Graphical symbols for use on equipment - Part 1 : Overview and application, - Part 2 : Symbol originals. (1998)

[3] CEI 60617-1 à 13 : CEI, Graphical symbols for diagrams - Parties 1 à 13. (1985 à 1997)

[4] CEI 60298 : CEI, A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV (1990).