FULLY MOTORISED CUBICLE LEADS TO MORE SAFE, RELIABLE AND EASY TO USE AIS SWITCHGEAR

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ABSTRACT

Full motorization of Air Insulated Switchgear inside primary Medium Voltage cubicle brings a lot of advantage in terms of safety and easiness of operation. It includes electrical operation of circuit breaker, racking device and earthing switch.

Proposing more systematically electrically motorized cubicles is the occasion to rethink their control architecture and to get benefit of digital technologies.

The aim of this paper is to analyse in a systematic way how they can help to ***optimize*** *motorization into cubicle with the* ***same level of performance****, proposing in the same time* ***new helpful functionalities****.*

INTRODUCTION

Architecture of Air Insulated Switchgear (AIS) is made of three main components that can be operated independently:

- The circuit breaker (CB) itself than can be opened and closed
- The racking device (RD) that allows isolating the feeder by racking out the circuit breaker
- The earthing switch (ES) that allows earthing the feeder before any intervention on it.

In traditional way, only the circuit breaker is electrically operated thanks to tripping and closing coils. The two other components are operated manually with levers.
More and more the advantage of motorizing them appears to operators and field engineers:

- Operation at safe distance of the cubicle, to reduce the risk of exposure to an arc flash which are more likely to happen at that moment.
- Guidance and diagnostic to help operator to achieve operations. Cubicles are complicated to operate. Electrical operation associated with self-understanding interface are very helpful.

Automatic operation of switchgear is quite simple, it is achieved by driving motors or coils up to the final position. The main critical point is more on interlocks that should forbid all operations dangerous for peoples, material or service continuity but bring a lot of constraints in cubicle and switchboard design.

In other technical fields, bringing electrical and electronical technologies has been the occasion of optimizing the global architecture and to add functionalities that was too complex to achieve with the traditional way.

CURRENT SOLUTION

<u>Based on mechanical interactions</u>

In complement of the three main components already mentioned, there are some different parts of the cubicle that must be taken into consideration when operating it:

- Closing of cable and circuit breaker compartment doors
- LV plug insertion
- Shutter movement to restrain access to live part
- Padlocking system

This leads to have numerous mechanical links, **table 1** below lists all of them. Links could be of three different types:

1) Interlocking of two moving elements, those interactions should work in both way, for example:

- Earthing switch could not be closed when the circuit breaker is racked in.
- Racking device could not rack the circuit breaker in when the earthing switch is closed

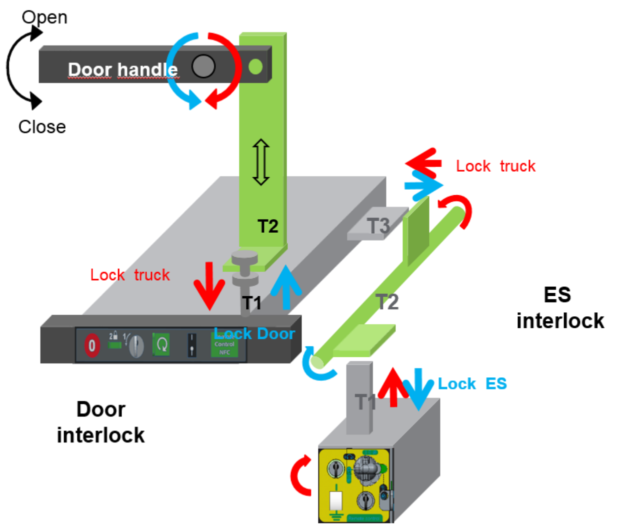
2) Automatic action of one element to another one, for example racking out the CB leads to close the shutter to prohibit access to live part.

3) Locking action. For example, padlock mechanism.

	Circuit Breaker	Racking Device	Earthing Switch	CB door	Shutters	LV Plug	Cable door
Circuit Breaker		I					
Racking Device	I,A		I	I	A	I	
Earthing Switch		I					I
CB door		I					
Shutters							
LV Plug		I					
Cable door			I				
ES padlock			L				

I: Interlock, A: Automatic action, L: Locking action

Table 1: Mechanicals links between different elements



en elements

Figure 1: Example of mechanical links between earthing switch, racking device and door

There is a specific case concerning racking out or racking in operations which are inhibited when CB is closed. To make sure it cannot happen, the interlock is associated with an automatic tripping mechanism that will open the CB if for some reason the inhibition was not effective.

Limits of current solution

All those mechanicals links are realized in-between different elements from different suppliers, sometimes with long levers, bars, complex shapes. Tolerances on dimension are sometime difficult to maintain especially in case of harsh environment, repetitive motion, interchange of circuit breaker, ... This can lead to quality issues, jamming, locking, breakdown, and even worse inoperant interlocking.

Image 1: Quality issue on a racking device

More advanced interlock need to take into account information coming from other cubicle or from outside of the switchgear. As mechanical interaction cannot be added, it is solved using a mix of electrical coils, driven by auxiliary contacts and having a locking effect or by a system of locks and keys that have to be used in a precise order. All those systems are complex to develop on each switchboard, and difficult to modify in case of evolution of the switchboard.

IMPROVEMENT THANKS TO DIGITAL INTERLOCK

Traditional way of bringing motorization into AIS cubicle is to add motors and sensors above the existing manual mode, electrical motor acting the same way as manual levers with the same interlocks but also the same limitations.

We propose to take the advantage of the flexibility of digital solution to simplify the mechanical architecture to:

- Reduce drastically mechanical interactions and then possibility of disfunction
- Add electrical interlocks to cover more cases for a safer solution
- Provide an easy way to adapt to specific cases

Operations of the switchgear will be fully motorized. Local and remote operations will be performed only electrically. Mechanical actions through lever or push button, will remain as an emergency way in case of digital disfunction.

METHODOLOGY

By simplifying the mechanical architecture, we should take care of providing the same level or even better level of safety than mechanical interlocks, especially in case of malfunction.
One of the main advantage of the digital solution versus mechanical one, is that malfunction can be detected and then:

- taken into account into fail-safe approach to avoid unsafe consequences.
- reported to maintenance team, limiting the latency time where the failure is present and then the probability of an unsafe effect.

A fail-safe component has been designed to not create a safety issue in case of failure. Under voltage coil is a good example of fail-safe component. A failure of the coil leads to trip the installation instead of letting it unprotected. FMEA methodology is used to determine failure possibility and safe response of the component.

Another point that must be taken into account is that digital solutions are dependent of power supply. Loss of power supply is then a degraded case that should be handle by a specific procedure. As fail-safe approach will lock operations in case of loss of power supply, specific access which require tools to operate will be provided in order to realize operations without power supply. Safety of the operator is then ensured by ultimate mechanical interlocks or step by step procedures.

We analyze all the mechanical links through a FMEA approach, answering to the following questions:

- How critical is that link. What are the consequences on operator and installation in case of failure.
- If we suppress the mechanical action and rely only on electrical one, can we provide a fail-safe solution, can we detect the failure or even better improve its detection by crossing more information.

If by suppressing the mechanical links and maintaining only electric one, failure of this last one does not lead to any critical issue, we suppress the mechanical link and we take the occasion to reinforce failure resilience and diagnostic.

RESULTS

Simplified architecture

	Mechanical action	Digital action
Racking device		
CB interlock	Suppressed	Redounded and fail-safe contacts
Trip CB during racking	Maintained	Check auxiliary contacts
LV plug interlock	Suppressed	Contact continuity check
CB door interlock	Suppressed	Fail safe coil
Earthing switch interlock	Suppressed	Redounded and fail-safe contacts
CB anchor interlock	Suppressed	Fail safe contacts
Automatic discharge	Suppressed	Automatic sequence
Earthing switch		
Racking device interlock	Suppressed	Redounded and fail-safe contacts Add CB open check
Cable door interlock	Suppressed	Fail-safe coil
Live cable interlock	Not possible	Add check VPIS/VDS
Earthing switch padlock	Maintained	Check contact

Table 2: Result on mechanical action

The **table 2** show how most of the mechanical links can be suppressed and replaced by electrical information only.
We kept as mechanical the automatic tripping in case of circuit breaker racking in or out because any failure on that point will lead to an immediate arc flash. Mechanical padlock of earthing switch is also maintained as it is critical for safety of maintenance operator.

This lead to a very simplified mechanism with very few mechanical interfaces where it remains:

- Only motors to move the racking device and the earthing switch
- Automatic tripping device as mentioned above
- Proximity sensor of mechanical position
- Coils to lock doors

In case of loss of power, procedure to rack out the CB will be:

1) Open the CB through the door using rod and mechanical push button on CB
2) Remove a cover with a screw-driver to access to truck screw
3) Insert handle and rack out CB. In case of point 1) has not be done, automatic tripping of CB would avoid arc flash
4) Unlock the door using a tool

Open to new functionalities

Having a full native electrically motorized and digitally controlled solution allow to think to new functionalities that are not possible or very complicated with classic solution.

Live MV cable interlock

This new interlock avoids earthing a live cable and the tripping of part of the network that would result of that, by testing the voltage presence.

It takes into account the voltage measurement from Voltage Presence Indication System (VPIS) or Voltage Detection System (VDS) and can be easily added to a digital interlock system.

Self-discharging circuit breaker

When extracting a circuit breaker from a cubicle, it is safer to discharge the spring before any maintenance operation on the circuit breaker. An OCO sequence can be automatically driven by native electrical control function without reloading the spring. The circuit breaker is then free of mechanical energy.

Motorized shutters

Shutters in classic solution are actuated with mechanical levers that should provide a large multiplication effect (figure 2).

Shutters are critical because failure can lead to internal arc or open access to live parts.

Electrical solution will be to replace them by a motor driven rolling shutter. Mechanism is a lot more simpler and most important, position of the shutter can be digitally controlled before engaging any move of the circuit breaker.

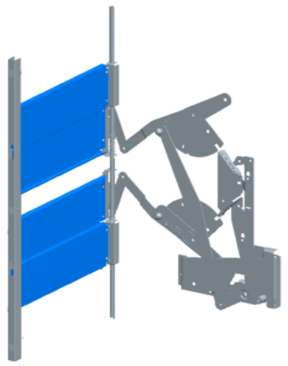


Figure 2: Lever system to actuate shutters

Bus bar earthing

Bus bar earthing is a difficult operation that need specific device and complex procedure.

In a native electrical solution as there is no mechanical interlock, specific arrangement to earth the bus bar (Earthing switch closed, with rack in and circuit breaker closed) can be achieved with the necessary control to ensure that the bus bar is not live.

This really easy way to earth the bus bar can be realized on different points of the switchboard for an even safer protection.

CONCLUSION

Electrical operation should not be thought anymore as a complementary option of the mechanical one. Designing switchgears as natively electrically motorized and digitally controlled, keeping the mechanical operation for degraded case, brings new possibility of architectures. Electrical links are simpler and more flexible than mechanical ones; They bring the possibility of self-control and fail-safe approach that allows improving the safety and reliability. Like in other fields, digital control open the door to new features to ease operation and reduce risk for operator and installation.