ACTIVE PROTECTION AGAINST INTERNAL ARCING FOR OPERATORS AND EQUIPMENT PROTECTION

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ABSTRACT

The operator safety against internal arc is guaranteed by passive protection system (e.g. the switchgear structure). In this paper, a new concept of active protection system integrated on the UniGear switchgear is presented.

INTRODUCTION

Modern Medium Voltage AIS and GIS switchgears are designed for guarantee the operator protection against internal arc. This is achieved by the design of the switchgear envelope, which is capable to withstand the pressure and heat generated by the arc and by the installation of exhaust duct for directing the hot gases far from the operator-working zone.
This safety concept is dedicated to the working personnel, and the duration of the phenomenon is limited by the selectivity of the relay protection system.

If an arcing fault occurs, the energy released in a fraction of a second can result in serious injury or death of the operator [1].
There is a great challenge in getting the message to the people of electrical industry so that safer system designs and safer work procedures and behaviors result.
The foremost consensus standard on electrical safety is the NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces" [2].
In the above mentioned standard it is clearly stated that workers should not work on or near exposed live parts except for two demonstrable reasons (NFPA 70E-2000 Part II 2-1.1.1):

1. deenergizing introduces additional or increased hazards (such as cutting ventilation to a hazardous location) or
2. infeasible due to equipment design or operational limitations (such as when voltage testing is required for diagnostics).

Financial considerations are not an adequate reason to work on or near energized circuits. To violate these regulations and practices is a violation of law, punishable by fine and/or imprisonment.

So no matter how well a worker follows safe work practices, there will always be a risk associated with electrical equipment, and there are some occasions where it is necessary to work on energized equipment (for example, when a problem cannot be uncovered by troubleshooting the equipment in a de-energized state).

CURRENT LIMITING DEVICES

In case the operator is obliged to work on a system kept under voltage, it must be considered that with conventional protection relays the minimum time required for the extinction of the fault is in the 100 ms range. During this time, the operator is guaranteed by the switchgear structure, which is tested normally for 1 s or for 0,5 s, but the electromechanical equipment is internally completely destroyed by the arcing. In fact, in the first 120 ms it is included the dynamic phase of arcing, with development of high pressure and expansion of the hot gases in the cubicles.
This equipment failure causes high costs for repairing, problems of service continuity and long process insurance claims.

Current limiting devices can reduce both the magnitude and duration of the fault current. A current limiting device must be capable to operate in the first quarter cycle and prevent the fault current from reaching the first peak of the asymmetrical waveform, significantly limiting the total electrical energy delivered to the fault.

In the ABB product portfolio several fault protection systems are available, such as I_s Limiter, Arc Eliminator, TVOC, REA, FRD and I_{th} Limiter.
All these devices (except I_s Limiter and Arc Eliminator) are usually installed in ABB switchgears, but the average required intervention time for the fault extinction is in the 100 ms range, considering the relay and circuit breaker time.
I_s Limiter can be installed in a dedicated switchgear unit, used as a fast bus-tie disconnecting device which enables distributed generation connection or system extension when the coupled short circuit power will exceed existing switchgear ratings.

The I_s limiter solution, due to the extremely fast decoupling time of 1 ms and the need for the replacing of the interrupting device cartridge, is on a higher performances, economic value and investment level than the other solutions.

ARC ELIMINATOR

The Arc Eliminator (AE) is the solution which merges all the positive characteristics of all the above fault limiting devices: it can guarantee fast intervention time (around 5 ms) and is easily applicable in switchgears with limited investment.

Physically the AE is a fast closing earthing switch contact, one for each phase connecting to the ground. The actuating energy for contacts is electrically stored under continuous supervision [3].
Light sensors provide the tripping signal through the AE Control Unit (ECU).
In case of an open arc fault in the switchgear high voltage compartment, the light sensors will trip the contact system and make a complete short circuit within less than 5 ms from the instant of light detection. The arc requires a voltage of at least some hundreds volts in order to persist. After the contacts are closed, the voltage drops suddenly to a value of which the arc cannot persist i.e. the plasma channel will not be able to carry electrons.

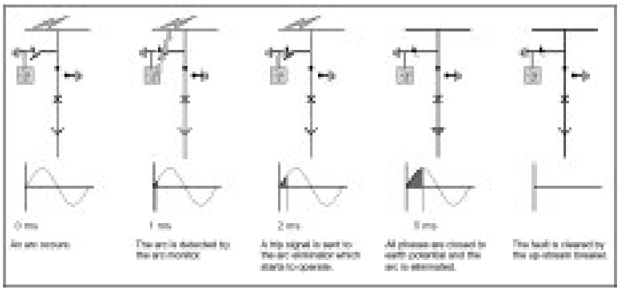

Fig. 1. Arc Eliminator circuit – event description

Initially developed and patented for AX1 AIS and installed in the Nordic market [4], the AE is now available integrated in UniGear AIS switchgear family and as standalone device to be used in existing switchgear plants.

In UniGear, the AE is installed in a dedicated metal box on each busbar system, and the arc is detected by fiber optics applied in every switchgear compartment. Thanks to this application, the damage of the equipment is case of internal fault is greatly limited, with significant advantages in terms of safety, costs and service continuity.

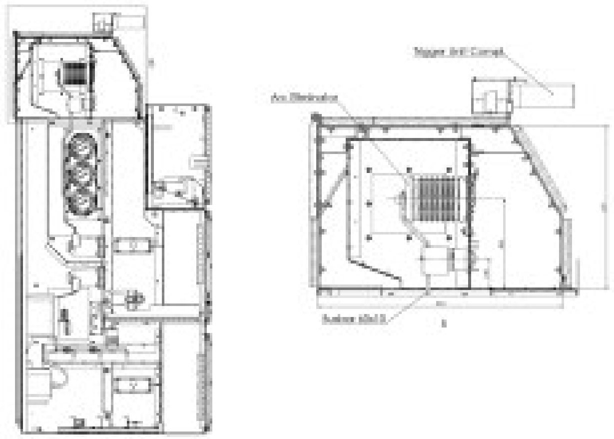

Fig. 2. Arc Eliminator application on UniGear

The installation of the AE on existing switchgear plants provides an "active" protection system (like ABS in braking systems), capable to detect and extinguish the fault in few milliseconds in order to preserve the electric equipment, with the additional benefit of the increased protection level for the operator ("airbag" concept).

The AE on UniGear was positively tested in CESI labs for the following parameters:

- three-phase short-circuit making tests; test duty T100s (a) with a prospective peak current of 66 kA at 24,6 kV (Test Report A6/004406) [5]
- three-phase short-circuit making tests; test duty T100s (a) with a prospective peak current of 82,1 kA at 12,1 kV (Test Report A6/004285) [6]
- three-phase short-circuit making tests; test duty T100s (a) with a prospective peak current of 100 kA at 12,1 kV (Test Report A6/004285) [6]
- three-phase short-circuit making tests; test duty T100s (a) with a prospective peak current of 82,4 kA at 17,5 kV (Test Report A6/004285) [6]
- three-phase short-time withstand current test with 31,5 kA for 3,01 s (Test Report A6/004285) [6]
- three-phase short-time withstand current test with 40 kA for 3,01 s (Test Report A6/004285) [6]

In the following oscillogram the three phases contact closing sequence are represented.

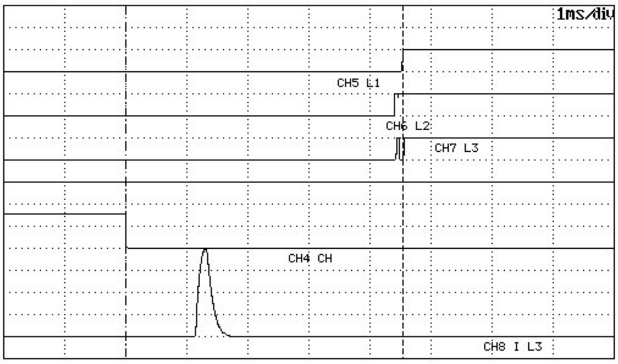

Fig. 3. Arc Eliminator making operation oscillogram

In the oscillogram the three phases are represented separately in the first three lines. The fourth line (CH4) is the trigger signal and the fifth line is the current flowing in the coil of the AE L3 phase. As it can be seen from the diagram, the trip operation is done in about 4,55 ms.
The AE electronic module is suitable to manage up to 6 optic fibers plus 1 electric input.
Since the UniGear panel is provided with three physically separated high voltage compartments (busbar, circuit breaker and cable), the AE is capable to cover up to 2 panels with 1 optic fiber for each compartment.

In order to increase the number of panels which can be protected by one device, we have developed a special electronic interface in order to connect the AE with up to 5 TVOC devices, each equipped with 9 optic fibers.
So, it is possible to protect up to 17 panels with a single AE device.
The tripping time is not affected by the presence of the TVOC.

NEXT STEPS

The remaining work to be done on the AE application on the UniGear panel is relevant to the determination of the maximum number of panels which can be protected by a single device, considering the impedance of the power circuit.

In the following picture it is represented the circuit we have simulated, in order to verify that the impedance of the power circuit from the incoming panel to the AE short circuit to ground in parallel to the arc is small enough as a function of the distribution system architecture, and therefore the voltage drop supplying the arc decreases at the AE operation in order to permit the extinction of the arc itself.

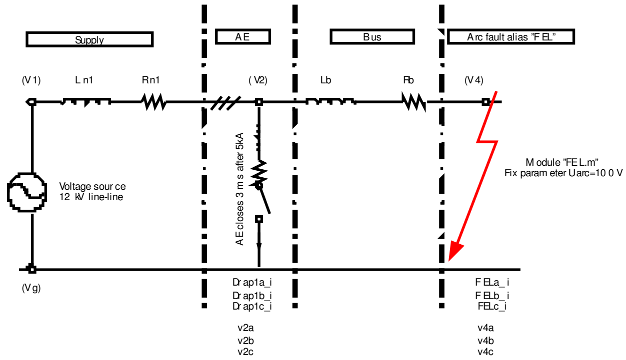

Fig. 4. Simulated circuit

Starting from the measured values, we have calculated the model based on the following data:

L_B = 1,8 μH (busbar inductance)
R_B = 0,15 mΩ, representing 4 panels (busbar resistance)

Simulation cases corresponding to 4 and 20 panels have been studied. The preliminary results show that the current sharing between the fault and the AE is not a problem even with a relatively large number of panels.
It is also clear that the L/R ratio influence the current wave shape and consequently the arc extinction capability.
Larger L/R value makes a slower decay of the DC component, and the arc lives a little longer.

The remaining part to be studied is relevant to the effect of bus capacitance, cables and transformers.

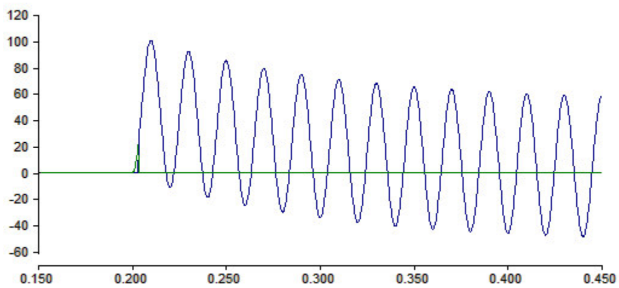

Fig. 5. Current switch between arc and AE

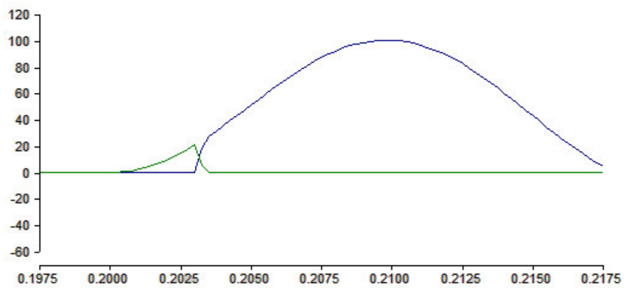

Fig. 6. Current switch between arc and AE (enlarged)

Referring to Fig. 5 and 6, the green path represents the arc current, while the blue path is the current flowing through the AE after tripping.

CONCLUSIONS

Operator safety is the first priority to be taken into account for a MV Equipment manufacturer. The solution presented in the paper is simple, easy to install and cost effective.
Thanks to the characteristics of the design (installation on a top mounted box), the AE for UniGear can be applied with great flexibility on each panel without the need for special arrangement on the panel itself.
The availability of the AE Service Kit for the installation on existing plants gives the possibility to the customer to increase the safety level of his existing equipment with only minor modifications to the switchgear.

The installation of the AE will be designed case by case by the ABB Service Department, and all the relevant technical documentation and functionality simulation studies will be provided to the customer.

REFERENCES

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[5] CESI, 2006, Test Report A6/004406.

[6] CESI, 2006, Test Report A6/004285.