NEW APPROACH TO DESIGN OF ADVANCED ETALON-TYPE SWITCHGEAR

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ABSTRACT

The paper describes a design concept of the new air-insulated switchboard ETALON. The distinguished feature of this switchboard is an application of the combined switching module, integrating in its design vacuum circuit breaker (VCB) with mono-stable magnetic actuator and series three-positioned selector. The latter provides both disconnecting and earthing operations. Interlocks preventing operation of selector when VCB is closed and operation of VCB when selector is in intermediate position are also integrated in design of the switching module. Despite extreme compactness of the switchboard, advanced bolt- and rivet-free enclosure provides arc-proof behaviour that is proved by relevant tests. As a result ETALON has minimum dimensions among all air-insulated switchboards presented in the market today, i.e. 330mm width for 12kV, 20kA/630A and 470mm for 12kV, 31.5kA/1600A feeders.

INTRODUCTION

Design of currently existing switchgear is normally based on different combinations of two or three main apparatuses, i.e. switching module, disconnector and (or) earthing disconnector. Being detachedly mounted into switchgear cabinet these devices shall be linked by carefully adjusted interlocking system to provide reliability and safety in operations. As a rule it is rather difficult to achieve when components are designed and produced by different companies.

Besides, it becomes a common situation when increasing loads and new customers are in need of additional feeders for power supply but area of switchgear rooms, deeply ingrown into already existing city structure, can not be easily expanded. If even this expansion is practically possible it costs so much because of price on land and building materials that is usually hardly acceptable. The only way out is the installation of advanced extra-compact switchgear cabinets instead of obsolete and ponderous ones.
At the same time, compactness of switchgear shall not contradict with environmental friendliness, and SF6 gas as isolating medium should be completely avoided.

The above-mentioned reasons stimulated us to elaborate air-insulated ETALON-type switchgear which is proposed to be a concept for a long perspective. This concept is disclosed below.

THE TOTAL ARCHITECTURE OF ETALON

The total arrangement of metal-clad ETALON-type switching panel is shown in Figure 1 (dimensions refer to 12kV, 20kA/630A version).

The switchgear cabinet is subdivided into four compartments: low-voltage (1), busbars (2), switching module (3), and cable compartment (4). Low-voltage compartment, placed in the upper part of the cabinet, includes µP protection and control units and not considered in this article in detail.

Figure 1. The total structure of ETALON switching panel

The very core of switchgear is combined three-phased switching module based on monoblock design and incorporating vacuum circuit breaker (VCB) with mono-stable magnetic actuator and series three-positioned selector (see Figure 2). The selector provides both disconnecting and earthing operations.

There are three fixed positions of selector, i.e:

- EARTHED – the movable contacts of selector are connected to earthing circuits. When VCB is closed, the cable receptacle is earthed via movable contacts of selector.
- ISOLATED - the movable contacts of selector are connected to neither earthing circuits nor busbars. The isolating distances withstand 48kV of power frequency (1 min) and 85kV of BIL.
- CONNECTED - the movable contacts of selector are connected to busbars and provide current flow through main circuits of switching panel when VCB is closed.

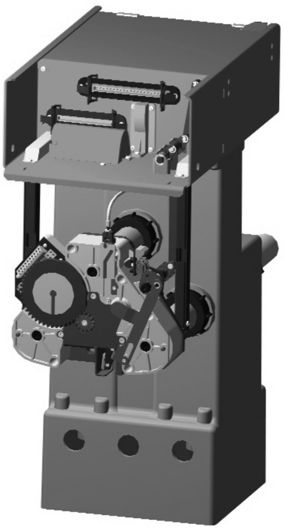

Figure 2. Combined switching module 12kV, 20kA/630A including VCB and three-positioned selector

If even operator mistakenly tries to move selector in an incorrect direction, the drive mechanism cannot be damaged due to ratchet-wheel interface that is a part of transfer system and limits torque applied to selector drive mechanism.

Interlocks preventing

- operation of selector when VCB is closed,
- operation of VCB when selector is in intermediate position, and
- withdrawal of switching module out of switchboard when VCB is in closed position

are integrated in the design of the switching module as well. That means that all separate high-voltage switching components used normally in “traditional” switchgear has been deliberately joined in a sophisticated and high-technology module, which actually is a new generation of equipment for medium-voltage switchgear. This approach prevents any hazard caused by poorly adjusted interlocks because this adjustment becomes a part of routine tests carried out by certified and well tooled switchgear manufacturer but hardly ever fulfilled by operating personnel in switchgear room.

The front side has a mechanical mimic circuit diagram arranged in a single-line format. The active segments of the diagram are unambiguously coordinated with drive mechanism of selector and magnetic actuator of VCB and clearly display all states of moving components. Elements of mimic circuit diagram are visible throw transparent inspection window that is a part of front cover of switchboard and made of extra-strong polycarbonate material.

Each phase of the switching module is connected to bushing including capacitive voltage sensor and current transformers (up to two units per phase for 20kA/630A and up to three units per phase for 31.5kA/1600A ratings respectively), placed in between compartments 3 and 4 (see Figure 1). If it is applicable for protection and control Rogowski coil can be installed instead of any current transformer.

Other side of the switching module is connected to busbar system, which is designed so as to provide displacement of switching panel without dismantling of adjoining ones. For the purpose connectors of busbars include multi-contact bands intended for high current, short time current included. Moreover, this design of connectors makes ETALON-type switchgear easily and fast mounted in switchgear room. Any main circuit of a substation or a distribution point is assembled by sliding of switching panels sideward to each other along metal frame over the cable duct.

RESULTS OF SIMULATIONS AND RESEARCH

The above-mentioned peculiarities of ETALON became embodied due to numerous PC simulations, tests and research work. Some results are described below.

Collet-type contacts of selector

Specially designed collet-type contacts are used in selector of switching module. The lamellae of these contacts are formed by optimal cutting angle (see Figure 3) and remain reliably connected to a mating part during peak withstand current up to and including 80kA. On the other hand, they provide more then two thousand EARTHED-ISOLATED-CONNECTED operations of selector without impermissible contact wear.

Figure 3. Lamellae of collet-type contact

Mechanical endurance of enclosure

Small dimensions of ETALON-type switchgear and necessity to withstand overpressure in the event of internal arc demand some specific conditions, i.e.

- high mechanical endurance of both frame and enclosure,
- high-speed operation of safety valves, and
- reliability and appropriate sensitivity of arc-fault sensors.

The ETALON meets all the requirements above.

For instance, rims of enclosure conform to the curvature of the cross-section of the aluminium frame. Frame and sheets of enclosure, clutched together, are additionally reinforced by rubber strip. As a result, the higher overpressure inside the fault compartment is, the more tightly the rim of enclosure is pressed to the edge of the frame. This clutch-design of interconnection is extremely strong and reliable.

To verify the impact endurance of proposed design of enclosure the switching panels were tested in Moscow Test Station (see e.g. Figure 4).

Figure 4. ETALON switching panel tested by 31.5kA internal arc initiated in busbar compartment. Front view. (Photographer Alexey Pasko)

All arcing tests were successfully passed notwithstanding that overpressure once attained to a maximum value of 1.8bar. Note that switchgear exterior being free of bolts, rivets and self-taping screws completely corresponds to pattern of modern industrial design.

Speed operation of safety valves

The rear side of each high-voltage compartment has a safety valve fastened to the frame by polymeric inserts. Quantity of inserts and their section is chosen to satisfy the contradictive requirements. Firstly, the safety valve has to keep its place if even the panel is influenced by vibrations and shocks corresponding to class 4M4 in accordance with IEC 60721 and IEC 60068 standards. Secondly, to be effective, the valve has to have minimal inertia to exhaust overpressure, caused by open arc-fault.

Each high-voltage compartment of samples was subjected to arcing fault with short circuit current up to 20kA or 31.5kA AC in accordance with ratings of corresponding switchboard. The arc duration was stated as 200ms. Arc-fault sensors are microswitches activated by safety valves released. The overpressure was measured by K-Line pressure transmitters manufactured by Kristal Instrumente AG. Typical process of overpressure in fault compartment and operation diagram of arc-fault sensor are given in Figure 5.

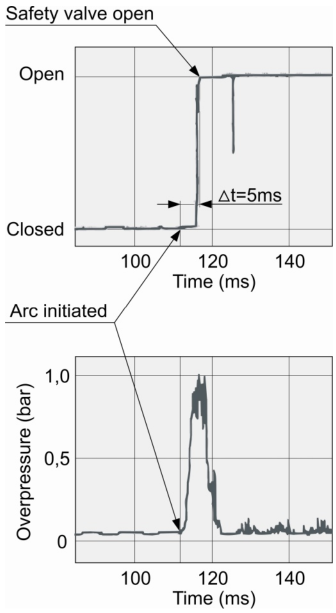

Figure 5. Operation of arc-fault sensor (upper) and overpressure inside fault compartment (lower) during internal arc test. Short circuit current 31.5kA, duration 200ms

These data show that after safety valve is open, overpressure drastically decreases and discontinues its ruinous impact while arcing is not completed yet. So, it is extremely important to release overpressure the sooner the better. In ETALON switchgear the speed operation of safety valves is not more than 5ms for 31.5kA and 8ms for 20kA.

Insulation of primary circuits

Despite the compactness of switchgear, insulation of primary circuits withstands 42kV of power frequency test voltage, 75kV of BIL and level of partial discharge applicable for power system with isolated neutral. These results are achieved due to numerous calculations of electrostatic field intensity, made for busbar system, switching module and bushings, and following tests of switchgear prototypes.

For example, monoblock, made of BMC material, is compartmentalized by barriers of sufficient, but not excessive thickness. Elements, which could initiate partial discharge in solid insulation are particularly smoothed and removed out of areas where electric field has undesirable level of intensity.

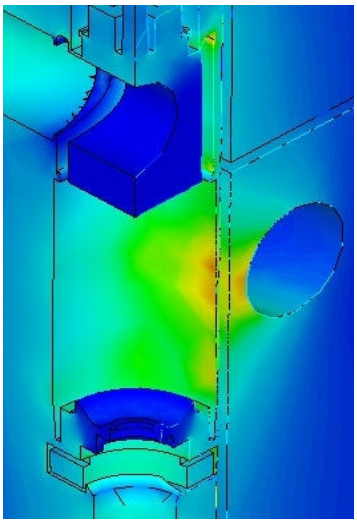

Figure 6. Optimal electrostatic field in 12kV, 20kA/630A switching module. Cross-section of 3D simulation

Results similar to shown in Figure 6 have made small value of pole-to-pole distance acceptable for 12kV switchgear.

CONCLUSION

As shown above thanks to intensive research work and application of modern PC software small dimensions of medium-voltage switchboard can be achieved without noxious isolating materials. Combined switching module elaborated by Tavrida Electric for ETALON-type switchboard originates new generation of sophisticated components applicable for extra-reliable and safety switchgear. The advanced ETALON concept is supposed to be a unique template for both today's usage and a further perspective.

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