RECENT TRENDS IN THE DEVELOPMENT OF FIXED SWITCHGEAR

ABSTRACT

This paper reviews the two main configurations of MV switchgear and advantages of both concepts in the light of user requirements. The paper then presents an improved fixed pattern design which goes beyond the requirements of users who specify withdrawable equipment.

INTRODUCTION

The market for MV switchgear is increasingly divided between conventional withdrawable designs, and the more recent concept with a fixed circuit-breaker. Withdrawable equipment was developed to allow simple maintenance of oil circuit-breakers. With the development of vacuum and SF6 circuit-breakers manufacturers have introduced fixed pattern equipment.

USER REQUIREMENTS

Operability and ergonomics
Traditionally supply authorities employed operators dedicated to operating switchgear in a relatively local area. With increasing regulation and competition operators are no longer restricted to local areas, but need to be able to operate a much wider range of equipment over a larger area. Manufacturers are being asked to design equipment, which is intuitive to operate, as well as paying more attention to other ergonomic factors.

Safety
With the introduction of internal arc tests in IEC 60298 and 62271-200 users are focussing on operator safety. Even if very few incidents are recorded, manufacturers are still required to prove the ability of switchgear to withstand the internal arc tests.

Fault location on cables is also an important function of switchgear: users are looking for designs which minimise the risks during this activity.

Environment
Increasingly users have to account for the environmental impact of equipment, both during manufacture and in service.

SCADA Control
Network regulators are imposing penalties based on the duration of supply interruptions. Users are therefore requiring switchgear with remote operation of all functions.

Availability
The costs and penalties of outages mean that it is important that the down time of switchgear is minimised: this means maximising reliability and minimising fault location, maintenance and repair times.

Cost
Users are looking for the most cost-effective solution over the lifetime of the switchgear. As well as purchase price the costs of erection, commissioning, maintenance and disposal at end of life are taken into account. The size will affect the cost of the building and is especially important at sites in cities.

COMPARISON OF WITHDRAWABLE AND FIXED DESIGNS

The advantages and disadvantages of the two designs are set out below.

Operability and ergonomics
Withdrawable switchgear requires the withdrawal of the truck and access to shutters for padlocking.

For fixed equipment all operations are carried out from the front: this leads to a simple operating interface

Safety
Isolation and cable testing provide access to HV conductors which may be live. Fixed equipment allows for interlocking to prevent access to HV parts except when they are earthed.

Failures can occur during the racking-in or racking-out of withdrawable parts. Such failures are not necessarily due to change of electrical field by the closing of the shutters, although this is one possibility. A more frequent failure is due to damage or distortion of the plugging contacts and/or the shutters such that a flashover to earth is initiated during the racking process.

SCADA Control
SCADA control of disconnection and earthing functions can be implemented using fixed types not generally possible with withdrawable equipment.
Availability
For withdrawable switchgear discharge at isolating contacts and round bushings can cause failure. It also has a greater number of moving parts and requires complex interlocks which reduce reliability. Fixed types eliminate these disadvantages.

Withdrawable breakers can be changed quickly in event of failure whereas this may be difficult for existing fixed types.

Cost
Fixed switchgear is less costly than withdrawable because of fewer components.

IDEAS AND DEVELOPMENTS TO IMPROVE FIXED SWITCHGEAR
A new fixed system (24 kV, 2000 A, 25 kA) is currently being developed at Eaton. The system provides some new features as well as optimized versions of existing features. Some key features of the system are now presented and discussed.

Figure 1 shows the side view of a feeder panel. This design was developed to give a balanced combination of features to meet users’ requirements. It incorporates qualities typically associated with fixed switchgear: i.e. safety, user friendly interface, reliability, low cost, small size. But special emphasis in this design was given to safety, availability and user friendly operability.

Design features
The panel is divided into two compartments with the two-position disconnector located inside a completely enclosed busbar compartment. This allows safe access to the CB/cable compartment with the busbars live since the two-position disconnector provides an earthed barrier between the CB/cable and busbar compartments.

Cable connections are at 750 mm above floor level to provide maximum convenience and working space for the person connecting the cables. Panels are 500 mm wide up to 1600 A and 750 mm wide for 2000 A.

All user interfaces are located at the front side of the panel to give minimum footprint and ease of installation and operation. The position indicators at the front are electrically operated or visible on the screen of the Protection and Control relay. The position indicators for emergency operation are visible on a mimic diagram behind the door of the mechanism and are mechanical operated.

The system is designed for full remote control of all the switching functions including disconnection and earthing. All the functions are electrically operated. In case of emergency it is possible to open the circuit-breaker with a mechanical lever.

The voltage transformer on the cable side is situated at the back of the cable/CB compartment behind the cables. An electrically operated disconnector is provided to disconnect the transformer: this can only be operated if the cable is earthed.

By using epoxy resin and vacuum interrupters instead of SF6 for insulation and switching the system can be classified as Green (environmentally friendly). The epoxy insulation allows the equipment to be as compact as SF6 insulated switchgear.
Special features

Ceramic arc absorber
The system features a ceramic arc absorber that effectively reduces the destructive effects of an internal arc. Each element has many extruded channels that together form a body of heat resistant material with a very large working surface - in this case 9 m². This absorbs a large part of the thermal energy and results in much less hot gas and metal vapour being exhausted into the switch-room. The absorber also limits the pressure rise in the switch room due to an internal arc. Figure 2 shows an absorber after a 25 kA-1s internal arc test.

Figure 2  Ceramic arc absorber

The absorbers for the Cable/CB compartments are mounted on the top of the exhaust channel. The arc absorbers for the busbar are on the ends of each busbar and on top of the sectionalisers.

Full single-phase epoxy resin encapsulation
The circuit-breaker, current transformers and cable side voltage transformers are mounted in a single compartment. This contributes to the simplicity, reliability, cost effectiveness and size of the design. Cable connections have usually been the most common point of failure, and hence users have required separate cable compartments to limit the effects of a failure. In the case of this design the epoxy resin insulation protects the other components and conductors from damage. Eaton (Holec) has many years experience of this technology which indicates that this type of encapsulation may be considered to function as a separate compartment.

Electro-Magnetic actuator circuit breaker mechanism
The circuit-breaker mechanism uses a simple and reliable EM-actuator that is maintenance free under normal service conditions. The construction of the mechanical linkage between the actuator and the drive rod of each of the three vacuum interrupters is also simple compared to a conventional spring charged drive mechanism. The mechanism uses only lubricant free joints and bearings. In a first mechanical endurance test this unit performed 37,000 cycles without maintenance.

Figure 4  EM actuator driven circuit-breaker

The mechanism of the two-position disconnector is based on the same design principles and can therefore also be characterised as maintenance free.

If for any reason the mechanisms require inspection or maintenance they can easily be accessed.

Closed system
The system is fully closed. There is no need for ventilation for cooling the hot-spots and because of that no dust pollution can reach the epoxy insulation. This avoids partial discharge on the surface of the insulating parts which can lead to degradation of the insulation.

Quick exchange facility for the circuit-breaker
The basic reason for switchgear being designed to be withdrawable was because of the frequent maintenance that was required for oil circuit breakers. Since vacuum circuit-breakers have a mechanical operating life of at least 10,000 operations and also have excellent electrical endurance, the interrupters are now maintenance free for most service applications. With the magnetic actuator mechanism having very few moving parts, and those being lubricated for life, there is now no need for any routine maintenance.

For applications with a very high number of switching operations the CB will need changing on an infrequent basis. For these cases a withdrawable system offers a significant advantage over fixed switchgear: namely the ability to exchange a circuit-breaker within minutes. With the new fixed pattern switchgear, when the ability to change a circuit-breaker is required by users, a facility can be provided that allows a circuit-breaker to be exchanged relatively quickly.
Each pole of the fixed circuit-breaker is solidly connected to the primary circuit, both mechanically and dielectrically, by means of $2 \times 3 = 6$ connection bolts situated at the top and bottom of the breaker: see figure 5A. The connection bolts are safely accessible from the mechanism compartment once the breaker has been connected to earth. On the busbar side of the circuit-breaker an earth connection is made by the two position disconnector; on the cable side an additional earthing device is required.

A simple hand operated pull/hoist tool enables the user to remove and subsequently re-mount a breaker of approximately 50 kg weight in a controlled and safe way. A suitable tool to enable the circuit-breaker to be quickly exchanged is shown in figures 5B and 5C.

The procedure for quick removal of the fixed breaker is as follows:
1. Connect circuit-breaker to earth on both sides
2. Remove door of panel and remove mechanical operation/interlock module behind door
3. Disconnect secondary connections from circuit-breaker (1 multi-pole connector)
4. Remove plates shielding the connection bolts and unfasten the bolts
5. Remove the cable compartment door and install the exchange tool on slotted holes in the door opening
6. Attach hoisting cable to circuit-breaker mechanism and position empty pallet on floor
7. Use a lever to loosen the circuit breaker from the tight primary insulating sleeve connections
8. Hoist circuit-breaker out of panel on wheels and down rails on exchange tool onto pallet
9. Unhook and remove circuit-breaker
10. Fit new circuit-breaker by reverse procedure

This procedure is expected to take about 1 hour; this assumes that the cable side of the breaker is earthed using an auxiliary earthing device fitted to the cable terminations. That part of the procedure would require a substantial proportion of the total time. As a quicker alternative it is possible to equip the panel with an additional integrated earthing disconnector on the cable side of the circuit-breaker. This could be located near or even combined with the VT disconnector (see fig. 1). With this disconnector the exchange cycle time would be reduced to less than 1 hour. With further development of the system the total time could be reduced to 10-15 minutes, comparable to that of a withdrawable system.

CONCLUSION

The new fixed switchgear with epoxy resin and vacuum interrupters, fully remote operation, application of arc absorbers, fully controlled cable test point facility and integrated earth facility provides more reliability and safety, is more cost effective and results in more compact switchgear. Added features make the equipment totally maintenance free. It is also possible to exchange a circuit-breaker in a short time with the busbar still in service.

REFERENCES