

EVOLUTION OF DISCONNECTING AND EARTHING FACILITIES IN MV SWITCHGEAR

Gerard SCHOONENBERG

Eaton Holec – The Netherlands
GerardSchoonenberg@Eaton.com

Wim MENHEERE

Eaton Holec – The Netherlands
WimMenheere@Eaton.com

ABSTRACT

MV switchgear has evolved from open systems in the old days into state of the art modern enclosed systems via several stages of development. Along with this evolution also the devices for disconnecting and earthing underwent their developments, together with the procedures for safe operation of and working on the electricity network.

After describing the specific topics related to the devices and procedures for disconnecting and earthing over the years, the paper focuses on both the 2- and 3 position disconnectors and earthing facilities, as they are both present in state of the art switchgear. The pro's and con's are treated, especially in respect to safety issues. For instance, the evolution from low speed earthing facilities into state of the art earthing via the main switching device has turned out to be an important point, primarily in relation to safety aspects, but also in regard to cost- and design considerations.

INTRODUCTION

Since networks were created to distribute electricity there is a need to connect and disconnect parts of it, both for availability and for safety reasons; e.g. separation of a faulty part, and service, maintenance or extension of the network. After the first hot-stick, operator dependent, switching with open blades, early developments soon resulted in fuses, disconnectors, Load Break Switches (LBS) and Circuit-Breakers (CB).

Especially a great role exists for the main switching device (CB or LBS). Because of the heavy demands on them, many further developments were concentrated on these components. The disconnecting function however, also has its existential reasons. Started in the past as the possibility to safely maintain the main switching device, its role for modern MV switchgear is not so obvious anymore.

Nowadays Electricity Boards want switchgear with a high intrinsic safety and low maintenance level, operable by relatively low-level trained operators. Main reason for this is the focus on costs, as a consequence of the market deregulation, taking place since the 1980's. This results in organisational and privatisation developments and changing liabilities.

Fortunately, today's switchgear indeed no longer needs as specialised operators as in the past thanks to their high

reliability, safety and very low need for maintenance. However, the majority of the switchgear presently in service is not of today's design.

After giving some more historic backgrounds, up till the development of integrated disconnectors and fixed design switchgear, the place and functionality of disconnectors is discussed in this paper.

HISTORIC BACKGROUNDS

When the electricity supply industry started at the end of the 19th century, there was a need for apparatus to collect, to control and to distribute the generated energy. This led to the construction of switchboards suitable for the voltages of that time and which we would now classify as low voltage (LV) open type switchboards. With the development of the electricity supply the power consumption increased, so an evolution into medium voltage (MV, ≤ 52 kV) open type switchboards took place. So far the development of switchgear evolved in the same way in the different countries.

In the United Kingdom, the development of the MV switchboards continued as the development of an industrial product, because switchgear, as the name states, is always considered as a complete component of an electricity supply system. Especially Reyrolle in England introduced at the start of the 20th century its so-called metal clad switchgear for the range up till 11kV.

In the Netherlands the Reyrolle concept was already adopted since the early 1920's, and the manufacturers of MV switchgear had since then produced metal enclosed oil filled or compound-filled switchgear in one or another form. Other developments led to the solid insulation-enclosed switchgear since the 1960's.

In Germany, as in most of the European countries, these MV switchboards evolved into installations, an assembly on site of components for the different functions of a switchgear like for the high voltage (HV). In this respect also the name 'HV switch-installation' (Hochspannungsschaltanlagen) is typical. As a consequence the industrial development was focussed on the components that stimulated standardisation and mass production. On the other hand the layout, the connections of the components and the safety was in many cases left to the user or a contractor.

Nowadays, for the medium voltage (MV) almost only enclosed switchgear is used for new installations. For the higher (HV) voltages, still the open type installation prevails, although compact metal enclosed switchgear is also available nowadays. Obviously economic reasons play their role.

INTEGRATED DISCONNECTOR FUNCTION IN MAIN SWITCHING DEVICE

There is a tendency to let the Main Switching Device (MSD) also perform the disconnector functionality (like in the early days of electricity) based on economical reasons. Developments are on their way (both for MV and HV) to integrate this disconnecting function into the main contact configuration of the circuit breaker itself [1][2], as is already the case for a longer time in SF6 Ring main units for the medium voltage, see fig 1.

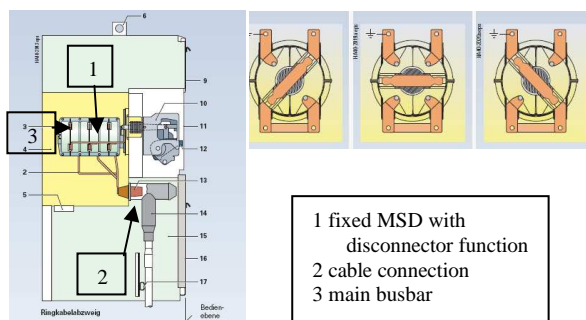


fig.1 SF6 ring main unit where the disconnecting function is not separated from the LBS or CB

Enabling technical reason for integrating the disconnector function is that a modern MSD needs less maintenance and is at least as reliable as the disconnector.

Conclusion from an international study, already performed in 1993 was that MV CB's have a MTBF (Mean Time Between Failure) of 1000 to 5000 years, where disconnectors have a MTBF somewhere between 250 to 1000 years [3]. Since then, no developments have taken place that might question the basic outcome of this study.

The only function left for the integrated disconnector is to create a safe isolating distance, so workers downstream can safely work on a de-energised part of the network. Any too high overvoltage in the live part will never flash across the open disconnector; the breakdown with corresponding transient currents and voltages will be along another path in the energised part of the network, due to the isolation coordination.

It is obvious that these integrated disconnectors cannot be used for access to the MSD itself.

Point of attention is that during the lifetime, where the MSD is supposed to break several times a (short circuit) current,

that the insulation inside the device stays at the same high level, as safety is involved. In general the generated by-products or contact wear during current interrupting could lower the isolation values e.g. near the main contacts [2].

It also has to be realised that the insulating "material" like SF6 or vacuum has to be present according to the specifications, for the proper dielectric behaviour. In other words, no leakages are allowed during the (long) period that the MSD must function as a disconnector. Although users do rely on SF6 in nowadays RMU's (see fig.1), the vacuum interrupter is not generally accepted as a safety device.

WITHDRAWABLE AND FIXED DESIGNS

The following principal designs for the switching and distribution nodes can be distinguished:

- A. open type installation
- B. enclosed switchgear (metal or insulation enclosed)
 1. withdrawable Main Switching Device (MSD)
 2. fixed design Main Switching Device

Type A: Nowadays new open installations are not built anymore for voltage levels $\leq 24\text{kV}$ because metal or insulation enclosed switchgear is that cost-effective that in general the compactness, easy of installation and maintenance friendliness are the decisive factors resulting in enclosed switchgear.

For the higher voltage ranges (e.g. above 100 kV) open installation substations are still widely built. The MSD is generally joined at both sides by a disconnector to create safe isolation when working at the MSD itself (e.g. for preventive or corrective maintenance), or for servicing the network downstream.

As already discussed, developments are there (for economical reasons) to leave out the complete disconnector in the substation, and integrate its function (like increased dielectric capability) into the MSD [1][2].

In fig.2 an example is given of an old 10 kV open type installation, as still in service in the Netherlands.

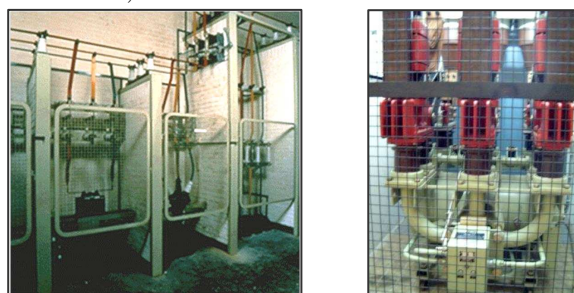


Fig 2 typical open type installations.

Type B1: Enclosed switchgear with withdrawable MSD originates from compact switchgear in the old days when the MSD needed relatively much maintenance. Also in case of irregularities, it was easy to exchange the complete MSD with a spare one. By taking out the MSD (see fig. 3), the

MSD was completely disconnected from both the busbar side and the cable side of the switchgear. The disconnection between the cable side and the busbar side of the fixed part was also automatically accomplished by withdrawing the MSD.

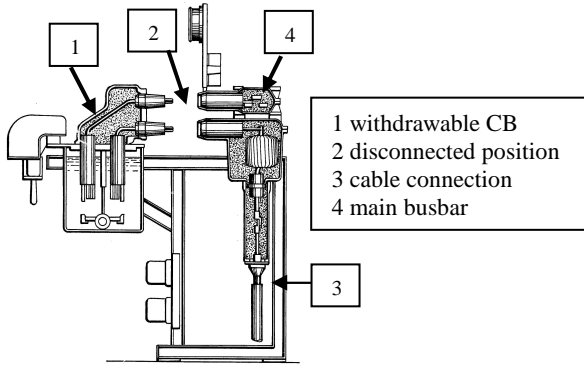
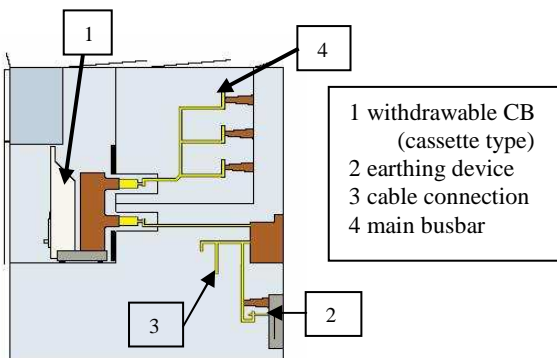


fig 3: withdrawable MSD in horizontal direction(1920)

Disadvantage of this principle is that the HV parts of the switchgear becomes accessible and therefore can be touched and that rely on shutters is needed at the moment that the electrical fields are changed. This is the case at the moment the MSD is withdrawn or re-inserted, so when the operator is standing in front of the switchgear. The majority of faults occur after maintenance or during operation.

Another disadvantage is that the MSD must be withdrawn or even removed, every time that access is needed to the network behind the MSD (it might be needed to insert some earthing device instead of the MSD). Another possibility, applied in more recent designs (from 1970's) is that a separate earthing device is already integrated in the



switchgear, see fig 4.

fig 4: withdrawable design with separate earthing device (1970)

Type B2, fixed design Main Switching Device (MSD): All the aspects above have led to developments of fixed design switchgear for distribution applications with an increase of safety and reliability by:

- Integrating all high voltage components
- Locating all high voltage components in a sealed compartment and prohibit access to high-voltage components

- Reducing the number of components and interlocks
- Forcing the operator to initiate a sequence of steps
- The possibility of full automation of the system

Fixed design switchgear became advantageous with the modern arcing media SF6 and vacuum [4]. Especially vacuum is sealed for life and needs no maintenance at all on the primary parts. With this technology it became possible to build almost maintenance free switchgear, where the mechanisms could be placed in the LV compartment. (see fig 5).

Today's switchgear with vacuum interrupters have a number of operations of up till 10.000 and at least 100 full short-circuit operations. In practice it is very unlikely that these numbers would be insufficient.

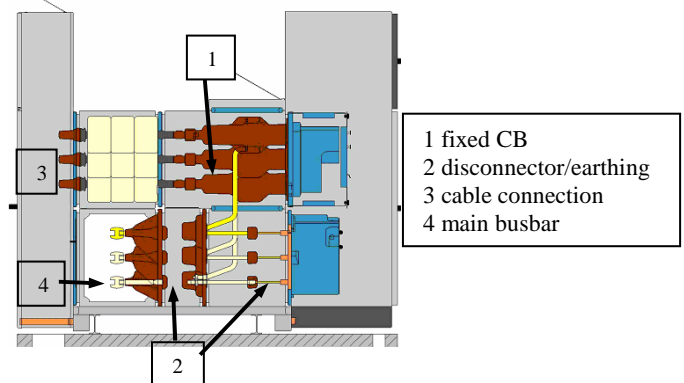


fig 5: fixed design with integrated disconnector/earthing device (2002)

With nowadays high MTBF figures for the primary parts, there is no need to enter the MSD compartment during service life. The often referred to disadvantage, that in case of a failure, no easy exchange is possible, is not really valid, as the only failure in this case is an internal arc. And after such an event more corrective measures are needed, also with withdrawable designs.

The disconnecting and earthing functions are normally integrated in the MSD for SF6 RMU designs (see fig.1), but this is not commonly accepted for vacuum interrupters (although developments are on their way in this respect). So, in case of vacuum interrupters, an extra component should be integrated to create the disconnecter function, as discussed in the next chapter.

DISCONNECTORS IN FIXED DESIGNS

The consequence of designing switchgear with fixed design Main Switching Devices (MSD's, circuitbreaker or load break switch), is that a separate disconnecter is needed, if the MSD itself cannot or may not fulfil this function; (e.g. as still is the case with vacuum interrupters).

On the other hand, this separate disconnecter can also be used for integrated earthing functionality, so no extra component, compared to the withdrawable designs with integrated earthing, is introduced. In this respect it is better to say "change-over switch"(COS) instead of disconnecter,

because the disconnecting function is realised by the opened MSD and the change-over switch in earthed position.

The choice then remains where to put the disconnecting facility and in which compartment: See fig.6, where four alternatives are presented.

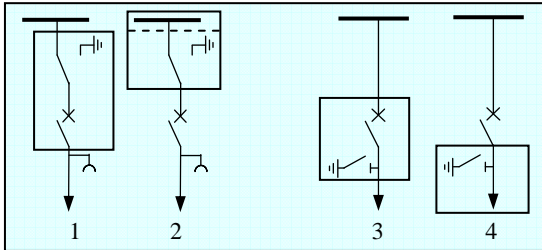


fig.6: several locations for the disconnecter in fixed designs

1. Upstream MSD, located in the MSD compartment: If also the earthing functionality is integrated, then the man independent, short circuit making capacity is added for free by closing the MSD after putting the disconnecter in an earthed position. Drawback of this physical layout is that the busbar shall be earthed before access to the MSD compartment is allowed. In case of failure of the MSD or the disconnecter, this means that the whole switchgear is out of service.
2. Upstream MSD, not located in the MSD compartment but in its own or in the busbar compartment: This layout is the most attractive, and is applied by many manufacturers in their recent designs. The advantages of alternative 1) apply also here, but higher availability is realised. For the rare case that access is wanted to the MSD, e.g. for exchange or in case of an internal arc, the disconnecter should be in another compartment than the MSD. Either the open contacts of the disconnecter are located in a separate compartment (as in fig.5), or they can be integrated in the main busbar compartment.
3. Downstream MSD, located in the MSD compartment. Although the electrical functionality to disconnect the downstream network is available, this layout is not optimal. The drawbacks of point 1) apply plus the more complicated mechanism for the earthing facility in case of short circuit making capacity.
4. Downstream MSD, located in the cable compartment: This layout is even worse than 3), as no safe access to the cable compartment is foreseen, unless the whole switchgear is de-energised.

2 VERSUS 3 POSITION DISCONNECTORS

For **double busbar switchgear** with the disconnecter/earthing facility upstream of the MSD, one 2-position and one 3-position disconnecter are necessary, where the 3-position also includes the earthing position, see fig. 7.

For **single busbar switchgear**, also when including the earthing facility into the disconnecter, there still is the

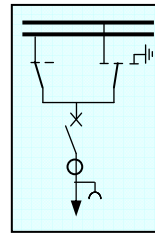


fig. 7: Double busbar

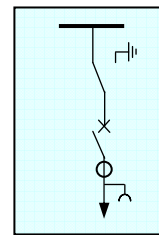


fig. 8: Single busbar

choice between 2 and 3 positions for this device.

For feeders and outgoing panels a 2-position disconnecter with earthing facility (COS -Change-Over Switch) (fig. 8) is beneficial compared to the 3-position device for the following reasons:

- Simpler and less components, resulting in higher MTBF
- Not less functionality:
 - The disconnected position is realised by the earthed position and the open MSD. Hi-pot cable testing is always done across the opened MSD to earth. The main busbar does not see other voltage levels than in normal service conditions.
 - Checking the downstream current transformers can be done from the cable side to the earthing point provided via the closed MSD.
- When the functional unit is in disconnected position, the integrated VDS (voltage detection) will generally indicate that no voltage is present at the cable side. In case the supply comes from the cable side (so the VDS indicates “voltage present”) it would be better from the safety point of view that breakdown to the COS in earth position takes place immediately instead of breakdown at the moment the operator is in front of the switchgear when he operates the disconnecter. This would be the case when a disconnecter was kept in a floating position.

It can be concluded that for modern switchgear, with the lay-out as presented in fig.8, the 3-position disconnecter is superfluous, and that the COS has the benefits.

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