

# FIXED OR WITHDRAWABLE SWITCHGEAR

*Withdrawable switchgear, past or future?*

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## **Abstract** – RO-15

This paper focuses on medium voltage switchgear in withdrawable execution, compared to medium voltage switchgear in fixed execution. Looking at the benefits and disadvantages of both executions, and the function the switchgear has to fulfill.

Elaborating both executions, investigating accidents and near accidents; analyzing the causes, and studying the possibility of unsafe operation.

Giving a clear picture on the total cost of ownership, including the reliability, availability and peripheral influences, such as; cable connection, switchroom size and process control connection.

Also looking at operator friendliness, how easy is it to work with the switchgear, how complicated the switching procedure is, and also looking at how complicated conducting maintenance inspections, or maintenance measurement is.

The aim of this paper is to provide a clear guideline as to which type of execution is favourable, in a specific situation, taking into account the newest technologies in switchgear and network architecture.

After a short introduction to medium voltage switchgear and their applications, the first part of this paper will describe the main aspects, like safety, reliability and cost, of both withdrawable and fixed executions. Followed by chapters that explain the different aspects, to be considered when purchasing a switchgear. Additionally the situations of usages is highlighted. Followed by a chapter that compares fixed and withdrawable medium voltage switchgear. The paper finishes with a hint how to choose between fixed or withdrawable medium voltage switchgear.

*Index Terms* — Fixed medium voltage switchgear or Withdrawable medium voltage switchgear.

## **I. INTRODUCTION**

From the moment electrical energy was transported and distributed, the need for switching became apparent. Switching medium voltage, during the pioneering days of electrical distribution, was a challenge. Since then there have been big changes to switchgear, and their form of execution, and still new technologies and insight are changing the “optimum” execution.

Medium voltage switchgear have evolved, from open systems (like indicated in figure 1) in the old days, to state of the art, modern enclosed systems, via several stages.

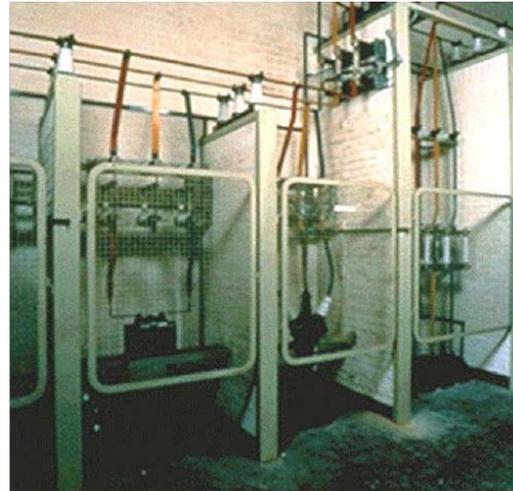


Figure 1. Old days, open medium voltage switchgear

After the first air insulated switchgear, the development of medium voltage switchgear evolved into oil filled switchgear. The big advantage of oil filled switchgear was the reduction in required space for the installation. Due to the characteristics of the used oil, the oil helped to insulate the medium voltage parts. The installation became “safe to touch”, and no additional screen was required. Inside the switchgear the oil distributes the heat, generated by losses. This made it possible to further reduce the switchgear. In smart designs, the oil helped to extinguish the arc in the opening breaker. But oil filled switchgear behave badly. If they are pushed past their limits, the oil will combust. To prevent this from happening frequent maintenance is recommended. (check once a year, or every 2000 times switching, and perform lifetime extending maintenance every 5 years, or 5000 times switching). To make this frequent maintenance possible, the first withdrawable switchgear were developed. All parts that require maintenance are placed on a wagon that can be easily and safely withdrawn from the switchgear, and reconnected after maintenance is complete. This allows for minimum disturbance to the connected load.

After some bad experiences, the market required a less “combustible” medium voltage switchgear, without increasing the size of the switchgear. Some manufactures solved these issues by using an insulating gas (SF<sub>6</sub>). This gas is used for insulating and extinguishing the switching arc. Other manufactures used cast resin insulation and vacuum bottles as switching devices. The maintenance requirements on this switchgear is reduced to such a low level that manufactures call them maintenance free (visual check once every 2-5 years). These newer

switchgears are executed in both fixed and withdrawable execution.

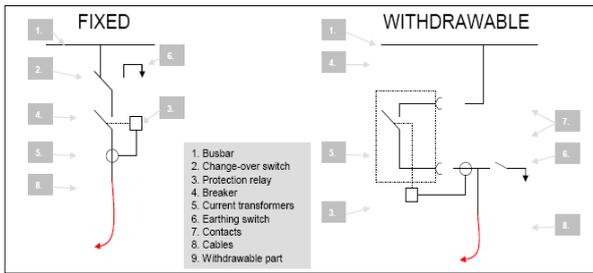


Figure 2. Diagram Fixed and Withdrawable breakers.

Figure 2 shows a simplified diagram of both the withdrawable and fixed execution of a medium voltage switchgear. In the withdrawable execution the withdrawable part contains the breaker and the protection, isolation of the outgoing cable is realized by removing the breaker. In the fixed execution an disconnecting switch needs to be added to make isolation possible.

During the evolution of switchgear, from open systems to enclosed, the switchgear with withdrawable main parts surfaced. The need for withdrawable main parts, was and is always, dependant on several factors that are highlighted in this paper, and compared to current insight and requirements. This comparison is not brand or type related.

The discussion about fixed or withdrawable switchgear has been going on since the first switching device was easier to disconnect than a fixed mounted execution. This paper focuses on indoor, medium voltage switchgear.



Figure 3. State of the art, fixed medium voltage switchgear



Figure 4 State of the art, withdrawable medium voltage switchgear

## II. ASPECTS OF MEDIUM VOLTAGE SWITCHGEAR

During the evaluation of purchasing of a new medium voltage switchgear the following main aspects are reviewed:

Safety, reliability and economics.

### A. Design Safety

In the early part of the 20<sup>th</sup> century, medium voltage switchgear were of the open conductor construction, housed behind wire cages. This type of switchgear used operator dependent breakers. The inherent danger of this design, resulted in accidents and fatalities and brought about the need for the specialized operator. Nowadays safety of the switchgear should not, and can never be, an issue when selecting a new medium voltage switchgear. The switchgear purchased, should have safety featured in its design. It should at least comply with the following international standards:

IEC 62271-1 Common specifications

IEC 62271-100 Circuit-breakers

IEC 62271-102 Disconnectors and earthing switches

IEC 62271-200 Metal enclosed switchgear

Accidents with medium voltage switchgear causing human injury and even fatality, are rare. The few reports that exist on these accidents, show that they are caused by interlocks that malfunctioned (broken or tampered with). Interlocks that prevent dangerous operation, like entering the cable connection room with live cables.

A reoccurring cause of accidents, is a foreign object that is left on the withdrawable part after maintenance. If the withdrawable part is then re-inserted the foreign object connects the primary parts and causes an arc flash. Registered accidents describe different foreign objects left behind after performing maintenance, for example: a tool, a phone, test wires and loose secondary wires) [3] [4] [5]. A large group of accidents occur when people are maneuvering the circuit breaker in and out of the switchgear.

### B. Reliability

In the Petroleum and Chemical Industries production is often a continuous process. Continuity is dependent on the reliability and availability of the electrical power supply to all process equipment.

Basic availability law, dictates that availability can be increased, not by changing the failure frequency of a device, but by shortening the repair time, also known as MTTR (mean time to repair). This involves making all devices easy to repair or replace [2]. This strategy is also known as minimum down time, and this is the main reason withdrawable systems were developed.

But on the other hand the failure frequency of a system, is increased, if it consists of more parts. Adding parts to a system will increase the overall failure frequency. Consequently removing parts and simplifying the system will improve the availability. A withdrawable medium voltage switchgear consists of, all the parts that are used in a fixed switchgear. To make a switchgear withdrawable parts need to be added. Additional parts are needed to make connection and disconnection, possible. For example shutters, align gliders, wrecking spindles,

signaling contacts, mechanical interlocks, main contacts, ect.

### C. Economics

Looking at the costs of a switchgear we are always tempted to only look at the initial outlay. Most likely this is the amount to be paid to the switchgear manufacturer. However the switchgear needs to be placed in a switchroom. The switchgear needs to be connected to the supply and loads, and the switchgear needs to be connected to the process control. Further more the operation staff need to be trained and the procedures need to be adjusted to the “new” switchgear. The sum of all of these expenditures needs to be considered in the initial economic evaluations. Certainly because these are different for each type of switchgear. For example: withdrawable switchgear often have a bigger footprint and need additional floor space to handle the removable part.

Total cost of owning a medium voltage switchgear should include more than only the Initial coast; as indicated in table I.

TABLE I

All Cost of owning a MV Switchgear
Initial cost
Building cost
Cost for connection load and supply
Cost for connection to process control
Cost for Training
Cost for maintenance during the life time
Energy cost losses
Cost of demolishing after life time

### III. ADDITIONAL ASPECTS MEDIUM VOLTAGE SWITCHGEAR

When evaluating cost prior to purchase of a new medium voltage switchgear there are also additional aspects that should influence the final decision. These additional aspects are less easy to pin point as they are not simply yes or no decisions. Additional aspects like; operational friendliness, risk reduction, visual separation, skilled operators, site culture, maintenance, process control and environment.

#### A. Operational friendliness

Medium voltage switchgear should have a user friendly interface. It should be; clear, easy, smooth to operate, and good looking. Even though the operators will not directly mention this as an important factor it will certainly be evaluated on a less conscience level. Most important, is that the operation of the switchgear allows for the switching protocol, that is used on the site were it will be installed. For example; some sites will only allow for a cable voltage testing on an installation with a closed door.

#### B. Risk reduction

Safety is reducing risk to an acceptable level. The risks of medium voltage switchgear are only partly reduced by requiring a switchgear that conforms to all relevant IEC norms as mentioned under design safety. These IEC requirements do ensure that the switchgear is safe in its

design, but a part of the risk occurs during the use of the switchgear. The user will need to take appropriate measures to reduce the risk to the level they require. By giving the proper training and applying a proper working-protocol. As indicated in figure 5. [5]

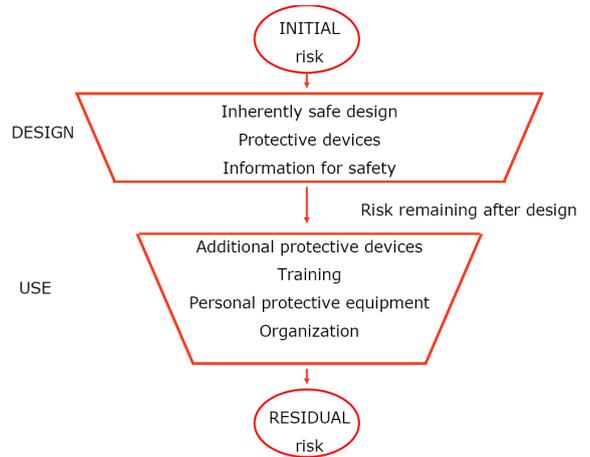


Figure 5. Risk reduction.

To be able to reduce the risks to an acceptable level, the switchgear needs to accommodate any further safety requirements that are needed. These additional requirements can be different per situation.

One of these risk-reducing measures can be the requirement to be able to insert and withdraw a breaker with a close door. A relevant demand since accidents have occurred during insertion of the circuit breaker. Unfortunately the IEC norms as mentioned under design safety only indicate that the “transfer of withdrawable parts” should not reduce the protection level. However a clear test for this situation is not required.

Some medium voltage switchgear even provide the possibility to maneuver the breaker via remote operated facility.

Another risk-reducing measure can be the requirement to be able to apply cable earthing simply and safely.

The possibilities of reducing the risks to an acceptable level, needs to be evaluated, considering the organization available.

#### C. Visual separation

Some users will require a visual separation to be able to reduce the risk. The main advantage of a withdrawable system, is that a clear visual separation of the switching device can be realized. At some sites it is mandatory to remove the breaker, close and lock the door, before mechanical maintenance can be performed on downstream equipment. In this way, the mechanically skilled maintenance worker can control his own safety. In earlier days there were configurations with one withdrawable breaker and two positions to connect it. As an alternative for switching one breaker off and the other one on. The whole breaker was moved from one position to another. For instance to choose between two supplies. This practice insured a safe interlock and it saved money.

Reducing risk by using a withdrawable system for visual separation is a contradiction. It is visually clear that the downstream equipment is voltage free if the breaker is removed from the system. But the act of making the visual

separation has raised the level of risk. Certainly compared by the operation of a disconnecting switch in a fixed execution. IEC norms, as mentioned under design safety, do not define “visual separation” but it is clear about giving fail-safe indication of the status of switching devices. Such as a disconnecting switch that is used in a fixed execution.

*D. Skilled operator*

There is a culture change going on, with the medium voltage switchgear operators, moving from dedicated switchgear operators to all-round troubleshooters. Up to 20-30 years ago the operator for a medium voltage switchgear was a trained specialized operator. This operators sole task was to perform the switching operations of “his” network. Many organizations are now requiring operators to also carry out non-operators tasks. Even non-operators are asked to perform operators duties. The design of modern switchgear are no longer “operator sensitive” and require less skill to be operated safely. The increased number of operation by less skilled operators requires that the “ease of operation” needs to be evaluated taking the available operation crew in to consideration.

*E. Site culture*

Each production plant or company have there own site culture. Often a bundling of knowledge, experience and best-practice for there particular use. Although this site culture varies from site to site there are some similarities with in petrochemical industry sites: Low voltage motor control centers have withdrawable motorstartes and high voltage installations are based on fixed breakers.

Medium voltage is less strict. Often sites are standardized on withdrawable installations but if gas filled installations are used it is fully accepted to use a fixed mounted breaker. But other sites will only opt for withdrawable breakers. It is an evaluation between reliability and quick access for maintenance.

*F. Maintenance*

Circuit breakers are mechanical devices, they will fail. It is important to know when they will fail. The most preferable moment of failing of the medium voltage switchgear is after its expected life time. But in those cases were the failure is expected with in the life time, preventive maintenance is required. To perform maintenance the breaker involved need to be disconnected from the supply. The increasing demand on the availability of the supply makes it hard to organize a planed outage. With a withdrawable system it is possible to perform the maintenance on a breaker with a minimized effect on the total switchgear. To maximize the advantages of this practice, all parts that need maintenance need to be on the removable part, including those that are likely to fail. Some withdrawable switchgear have only a withdrawable breaker, leaving other parts behind, such as; voltage-transformers, current-transformers, protection-relays, earthing-devices, ect. For maintenance on the fixed part of the main contacts, the withdrawable medium voltage switchgear needs to be de-energized. Similar to the work on an disconnecting switch on fixed medium voltage switchgear.

An other maintenance point to take into account is the

required disconnecting frequency, how often will the isolated situation be required. The allowed number of maneuvers of a withdrawable breaker is significantly less than the allowed number of open and close of a disconnecting switch in the fixed execution. Table II indicates the need for de-energizing the total medium voltage switchgear when performing maintenance activities. Both for fixed and withdrawable executions.

TABLE II

Need for de-energizing the medium voltage switchgear during maintenance activities		
Maintenance activity	Fixed	Withdrawable
Inspection / Replace on		
busbar	total	total
withdrawable main contacts	NA	total
disconnecting switch	total	NA
breaker	total (*)	not
earthing switch	total	not
shutters	NA	total
gliders	NA	total
mechanical interlocks on fixed part	total	total
mechanical interlocks on withdrawable part	NA	total

\*some smart solutions provide possibility for changing breakers without de-energizing.

When comparing fixed to withdrawable, the (still) mandatory maintenance and the down time it will cause needs to be weighed against the advantages that are gained, when the down time can be reduced.

*G. Process control*

Petroleum and Chemical Industry systems are controlled by a centralized process control. The centralized process control is connected to all devices within the process and in many cases the medium voltage switchgear needs to be connected to it as well. The costs for centralized process control, are normally related to the number of I/O points. The number of I/O points determine in the hardware required. And number of I/O points establishes the amount of programming hours that are applicable. Centralized process control primary task is to control the process and requires only basic information from the medium voltage switchgear. Information like statuses; on, off, isolated, earthed, test, withdrawn and fault. Sometimes even measurements are required to indicate the load. Withdrawable systems have more switching statuses that can be communicated to the centralized process control, and therefore there number of I/O points can be higher. Fixed switchgear do have less switch statuses, and therefore less to connect to a centralized process control. Maybe not the main consideration, but certainly an aspect that can be unexpectedly costly to implement.

On the other hand, a withdrawable switchgear provides a test position, that allows the centralized process control to operate the breaker external from the switchgear. Providing the possibility to test all signals without effecting the energy flow on the site. Most likely this is only an advantage during start up of a new system.

## H. Environment

Increasingly users have to consider the environmental impact of equipment, both during manufacture and service, as well as after its life time. In respect to the design, of a medium voltage switchgear, the vision "the least number of components, the better" applies. Because every part must be manufactured and therefore it has an impact on the environment. Furthermore the materials used, need to be selected carefully; they need to be safe for personnel and the environment – not just during use, but at the end of service life too. So that they can be completely recycled at the end of it's life without any problem.

Another environmental aspect is the energy losses in the medium voltage switchgear itself. The primary change-over points are mainly responsible for the energy losses in the medium voltage switchgear itself. A design that uses primary change-over points with optimal surface contacts will reduce the energy losses over these points.

## IV. USAGES

The aspects mentioned above get more, or less-important with the particular use of the switchgear. Like the position in the electrical grid and the function of the connected loads. If the switchgear is connected to a main position in the grid it is likely that there is a need for future changes and extensions.

It is important to know how critical the connected loads are. If the consequential loss of a down time is equal to the price of a breaker, it would be recommended to have a spare breaker available. But if the consequential loss of a down time is much higher, it would be recommended to use a totally redundant system that is always on stand by and can take over the supply, if so maybe a double rail system is required.

Further more it is useful to know how often the load will be switched on and off. If the breaker is connected to a distribution cable, it is likely it will only be infrequently operated . But if the breaker is used to feed a motor, it is possible it will be operated more frequently. The number of expected switching cycles of the switchgear is important, because switchgear is available in executions with less or more operational cycles. Mainly limited by the design of the operation mechanism that actuates the breaker. For distribution purposes, a total of 2000 switching cycles could be sufficient (looking at 30 years that is about 65 times a year). But for motor control a switching cycle of 30.000 could be to low.

## V. COMPARISON

When comparing fixed medium voltage switchgear to withdrawable medium voltage switchgear there are a lot of aspects to be evaluated. The evaluation should include the usage of the medium voltage switchgear. All aspects will be listed below and summarized.

### A. Safety

Both fixed- and withdrawable- medium voltage switchgear is initially safe. However accident investigation reports show more accident on withdrawable systems than that there are accidents with fixed systems.

### B. Reliability

Now it is getting interesting; if identical equipment is used, to make a fixed and a withdrawable system, then of course the withdrawable execution will need more parts and hence, have a higher failure rate. But if it fails it will be faster to repair.

### C. Environment

Both fixed- and withdrawable- medium voltage switchgear have an environmental impact. In general fixed switchgear have fewer parts, and therefore a lower environmental impact.

### D. Additional aspects

Comparing the additional aspect of fixed- and withdrawable- medium voltage switchgear there are small advantages and disadvantages. Looking from the users point of view, here listed in table II.

## VI. HOW TO CHOOSE FIXED OR WITHDRAWABLE

To make the right choice between fixed or withdrawable when selecting a new medium voltage system. The following evaluation procedure should be conducted: Find out how important the additional aspects are. Weigh up the financial implications and compare this to the additional total cost for a withdrawable system.

If none of the additional aspects are important (additional financial value at minimum) the balance will tilt to a fixed execution. But if one or more of the additional aspects are worth sufficient, it could be that a withdrawable system is to be preferred.

## VII. FINALLY

The title question was: Withdrawable switchgear past or future? The answer is clearly that the need for withdrawable systems is still there. Withdrawable medium voltage switchgear and fixed medium voltage switchgear do both have their applications possibilities. Therefore all major switchgear manufacturers do have both executions.

Within the Petroleum and Chemical Industry there is a belief that withdrawable medium voltage switchgear, will be easier to maintain and repair. In return this can result in reduced downtime. However current medium voltage breakers require less maintenance and are less likely to fail. Furthermore is it really worth adding additional parts to a switchgear to make it withdrawable?

Many users of withdrawable medium voltage switchgear indicate that this is needed for personal safety; visual separation for maintenance on downstream equipment. Is a withdrawable breaker wagon the best (safest) way to visualize a separation?

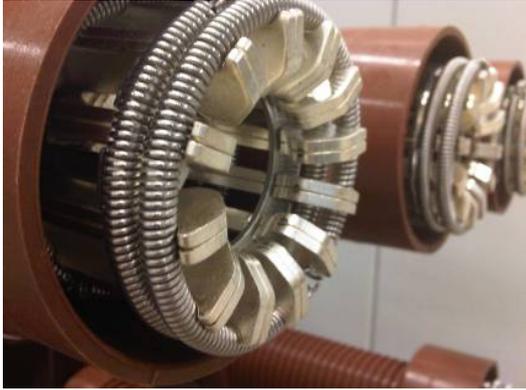


Figure 6. State of the art withdrawable self-aligning contacts

For safe maintenance activities on downstream equipment a fixed medium voltage switchgear can provide a safe separation with the disconnecting switch. With a fail-safe indication of the status.

### VIII. NOMENCLATURE

Glossary of terms used; Efforts have been made to use consistent terminology in this paper. However it is possible that other branches of technology use terms that are different from those used here. Therefore the list below gives synonyms for the used terminology:

TABLE III	
Glossary of terms used	
Terminology	Synonyms
Medium voltage Switchgear	1 kVac up to 52 kVac An electrical switchgear is a device that directs electricity from one source to another.
Fixed switchgear	Electrical switchgear with fixed mounted breakers.
Withdrawable switchgear	Electrical switchgear with breakers that are mounted on trucks that can be withdrawn and inserted in the switchgear.
Availability	The time for which a switchgear is fulfilling its function
Failure frequency	Frequency of failures (failures/yr)
Failure rate	The rate of the failures (e.g. one failure every 6 months).
Manufacturer Switchroom	Manufacturer of medium voltage switchgear The room specially designed to house the medium voltage switchgear
Main primary change-over points	The connection points within a medium voltage switchgear.
Breaker	Circuit breaker
Wagon	Structure to make the breaker maneuverable, also called truck.
Maneuvering	Moving the breaker to or from the connected position, also called racking in and racking out.

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