INTRODUCTION

The quality of the electricity supply has always been a point of major interest. Worldwide there is an increasing concern about Power Quality [1,2]. On the one hand social developments tend to an increasing dependence on a highly reliable electricity supply. On the other hand, developments on the electricity market lead to more competition, reduced costs, accountability for non-delivered kWs and kWhs, less maintenance, environmental aspects, operator safety, better customer orientation and satisfaction, etc. Both technology and market driven changes take place in electricity networks worldwide.

This paper describes the design and the main specifications of a new generation of indoor switchgear for 24kV networks. (Fig.1).

Fig.1: 24kV Ring Main Unit Xiria

After summarizing the present situation in the Netherlands, the boundary conditions leading to the chosen design for the new MV distribution switchgear are explained. The switchgear design - a safe, compact and effective solution in the network for the connection and protection of power transformers and cables is presented after discussing the revision of the existing standard for metal enclosed switchgear- IEC 60298 (third edition-1990).

TODAYS LAYOUT OF MEDIUM VOLTAGE CABLE NETWORKS

The distribution network is principally ring-shaped, and operated radially (in open rings). This creates a n-1 redundancy in the structure, but not in the operation mode. At the beginning of the open ring, a circuit breaker is placed in the feeding substation. (See fig. 2).

Fig.2: Typical MV cable network

A cable fault in such a system leads to an interruption of the supply, which can only be restored after a number of (manual) switching operations.

It appears that faults in the MV (3-20 kV) network are the cause of more than 75% of the approx. 20 annual outage minutes for an average LV customer in the Netherlands; 85% of these MV faults are created by cable / sleeve / connection faults. On average, a LV customer in the Netherlands is once per 4 years without electricity supply for the duration of one hour, due to MV-faults [3,4,7].

TRENDS AND BOUNDARY CONDITIONS

From a market driven point of view:

Electricity has proven to be an easy and efficient way of distributing energy to the consumer. Although energy consumption will be at higher efficiency levels in the future, the amount of domestic appliances using electrical energy is growing steadily. This results in an average yearly increase in the use of electrical energy of about 1-2% in the industrialized world.

Privatization of the electricity market has influenced the approach in several areas:

• Review of labor costs and labor structure
• A critical review of investments in the network
• Electricity changing from a right to a commercial product.

Liberalization has affected the structure and processes in the following areas:

• Less vertical integration between the stages in the production column of generation, transport and distribution
• Review of cross subsidies between the parts of the column or between customers (urban customers are not subsidized by rural clients).
• Larger distribution companies with improved "customer care", splitting up of activities for the control of the grid and for selling power through this grid.
A more rational decision process: a stronger focus on cost reduction.

The tasks for the distribution companies will change and grow and there will be a customer-oriented differentiation, for example with different levels of availability of power, tariffs and service.

There will be a greater need for information about energy consumption. Normal operation activities will however be done by less skilled (meaning less expensive) operators due to the necessary cost reduction, which is essential during the total lifecycle of the equipment. The liability of the distribution companies will be increased, so the insurance of their risks will become more important too.

Less time will be spent on maintenance, the applied equipment is expected to be maintenance free with a very high degree of reliability.

Environmental issues:

• The influence of the environmental discussions is still growing, possibly leading to the fact that the next generation of switchgear should contain environmental friendly materials.

• Thereupon this switchgear should also be recollected and dismantled at the end of it's lifetime in a safe way.

• A “clean and green” type of power will be demanded in future. This trend is shown on industrial level (triggered by legislation on the maximum amount of CO2, SF6 and other gasses in the atmosphere).

From a technical point of view:

• Increasing load of the electricity grid.

• Wide spread use of dispersed generation.

• Introduction of simple, economical vacuum circuit breakers that are maintenance free.

• Simple and safe operation.

• Optimization of load flow.

• Low maintenance or, even better, maintenance free.

• Compact design, but not too compact (proper handling shall still be possible).

• Green and clean (easy handling at end of life) design.

• Steadily reducing costs for intelligence, sensors and communication.

Nowadays the arcing media SF6 and vacuum are the only practical alternatives for newly developed medium voltage circuit-breakers. As a consequence of the reduced need for maintenance, or even to be completely maintenance free with vacuum, the switchgear designs nowadays evolve into fixed breaker designs. This evolution results in a higher availability against lower costs, compared to the conventional,drawable designs.

Also double busbar systems have their origin for an important part in the need of maximum availability against minimum costs and needed space (the other reasons to choose for double busbar designs are of course the possibilities of load control and short circuit power control). During maintenance work, e.g. cable testing, and repair, compartmentalisation inside the switchgear provides that the switchgear can remain in service.

Switching in vacuum

Within the Holec company a lot of experience has been gained over the last 25 years in the field of Vacuum Circuit Breakers (VCBs) and vacuum load break switches. Due to this long-term experience it is possible to manufacture safe, reliable and compact (vacuum) switchgear which can be combined with the described sealed for life medium voltage switchgear. (Fig.3)

Fig.3: 24kV vacuum interruptor

Holec has chosen Axial Magnetic Field AMF-interrupters because of the negligible contact erosion and the excellent switching performance at low and high fault currents. The benefit of negligible contact erosion makes this type of interrupter particularly suitable for use in non-withdrawable switchgear systems and sealed systems, because replacement of the interrupter during the technical life of the unit has become unnecessary. This also allows for the manufacturing of low maintenance, or even better, maintenance free switchgear.

Safety aspects:

Another very important aspect in nowadays switchgear design is the safety of persons. For the sake of safety, switchgear is very often equipped with interlocks that prevent unwanted access to live parts or disastrous switching actions in specific network situations, like the opening of a current carrying disconnector. Although some modern switchgear designs are such, that internal faults (open arcs) are in principle prevented, for the switchgear market as a whole, it is common practice to address the safety aspects for persons present at site during an internal fault.

Revision of the standard IEC 60298:

Besides the evolution in switchgear design, there is also an ongoing evolution in the international standardisation field. For the subject of this paper, especially the existing standard for metal enclosed switchgear- IEC 60298 (third edition-1990), plays an important role. At the moment, this standard is under revision. According to the documents that have been distributed till now (IEC TC 17C/283/CDV), the revised standard will also address modern switchgear...
designs, like fixed circuit-breaker systems similar to conventional systems (withdrawable breaker designs). Another important topic in the revision will be the internal arc classification and the definitions from the existing IEC 60298 standard for compartmented, metal clad and cubicle versus the thoughts behind these definitions concerning safety and availability. This will result for the revised standard in a new classification “Lack of Service Continuity”, when access is needed to an accessible compartment in the switchgear.

XIRIA, A NEW RING MAIN UNIT DESIGN

The area of application of the new switchgear (Fig.1) is the transformer substation in the medium voltage distribution network

The nominal ratings for 12 and 24 kV applications

<table>
<thead>
<tr>
<th>System</th>
<th>12kV</th>
<th>24kV</th>
<th>IEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>630</td>
<td>630</td>
<td>A</td>
</tr>
<tr>
<td>Impulse withstand voltage</td>
<td>75</td>
<td>125</td>
<td>kV</td>
</tr>
<tr>
<td>Power frequency withstand voltage</td>
<td>28</td>
<td>50</td>
<td>kV</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>50/60</td>
<td>50/60</td>
<td>Hz</td>
</tr>
<tr>
<td>Rated short-time withstand current</td>
<td>20/1</td>
<td>16/1</td>
<td>kA/s</td>
</tr>
<tr>
<td>Rated peak withstand current</td>
<td>50</td>
<td>40</td>
<td>kA</td>
</tr>
<tr>
<td>Internal arc resistance</td>
<td>20/1</td>
<td>16/1</td>
<td>kA/s</td>
</tr>
</tbody>
</table>

- Circuit-breaker:
  - Circuit breaker rated current: 200-200 A
  - Rated breaking current: 20/16 kA
  - Rated short-circuit making current: 50/40 kA
  - DC component: 35/35 %

- Load-break switch:
  - Rated current: 630-630 A
  - Rated breaking current (0.7 pf): 630-630 A
  - Rated short-circuit making current: 50/40 kA

Circuit breakers instead of fuses

A logical step was to replace the relatively bulky and expensive HV fuse by a circuit breaker (CB) to protect the transformer. (Fig 4) This has, amongst other things, the following advantages: [5,6]

- Losses reduced to about 5% compared to that of a fuse.
- No limitation in current ratings for the settings of the protection.
- Interruption of all possible currents, including those, characteristic to evolving faults.
- Possibility to be fitted with protection systems, which are independent of external power, with close discrimination with the LV fuses.
- No stock necessary for various types of fuses, minimizing

the making of mistakes.
- Suitability for remote restoration of the network.
- Increased safety: the medium voltage (live) internal parts of the switchgear don’t have to be touched anymore when changing the settings of the protection or restoring energy after a fault.
- Reduced maintenance: the medium voltage (live) internal parts of the switchgear can be fully sealed when there is no need for access to primary parts such as fuses, avoiding deterioration due to moisture and dust.

A possible drawback of CBs compared to fuses, is that there is no (peak) current limitation. This does not seem to be a point of real concern, since CBs typically protect larger transformers (above 1000 kVA). Of course, the costs involved are also a very important factor.

Many companies have already made a cost comparison between the total life cycle costs, plus the costs resulting from managing fuses versus the company procedures for circuit breakers and the non availability of the network.

Dedicated protection and control

The Xiria unit is provided with a newly designed and optimized electronic protection device that is kept simple and economic. The design has been focussed upon a high level of quality and long-term behavior instead of integrating all kinds of monitoring and sensing systems. Compared to the use of HV fuses this protection offers a better selectivity for nearly the same costs. The relay needs no external power supply but is energized from the current transformers and has independent and dependent characteristics. Maintenance is not necessary, resulting in a lifetime of 25 years or more at ambient temperatures between -40 and +85 degrees Celsius. Some aspects of the specification:

- Including self test circuit, the complete chain of protection can be tested
- Sealed for life design, all electronic parts are fully epoxy resin insulated
- Settings via laptop with dedicated software or a hand held controlCharacteristics: definite time, normal inverse, very inverse, extremely inverse, long time inverse, RI inverse, HV fuse characteristic.

Fit for future intelligent networks

Today’s switchgear equipment in the lower area of the medium voltage distribution is mainly hand operated Restoring power in the network takes time, depending on the
density of the network and the local circumstances regarding long distances or areas inaccessible due to heavy traffic. The described Xiria switchgear unit is basically hand-operated. However it can be used (and also upgraded after initial installation) as a fully remote controlled unit.

**Sealed for life design**

The medium voltage network is subject to a number of external influences during its total life cycle. Issues of aging materials like cables, connections and switchgear itself must be considered. As a switchgear manufacturer only the last item is dealt with in this article. The ideal switchgear deals with aging and slow deterioration of important medium voltage parts and mechanisms by avoiding the long-term influences. The "fit and forget" principle can be the solution for minimizing future disturbances in the network without paying attention to the components at all. Apart from smart design features based on acceptable electrical field strenghts, the new unit presented in this paper deals with this issue by sealing the major primary live parts in a sheet steel enclosure together with the operating mechanism, resulting in a sealed for life enclosure not influenced by the environment. (Fig.1) This sheet steel enclosure needs no attention, due to the fact that it is used under normal atmospheric pressure and filled with normal dry air. Also corrosion from within the unit is avoided completely during its lifetime.

**Environmental design**

Environmental impact of human activities has become a great-and often justified- concern in most of the countries worldwide. It has recently focused on potential climatic changes due to the increase of greenhouse gases content in the atmosphere. One of these (man-made) gases is SF$_6$, which is an essential material used in electrical applications. In fact, it is listed in the Kyoto protocol and consequently emissions should be duly reported. The electrical industry is the major user of this gas (>50% of total SF$_6$ production). [8,9] In Xiria however, the main construction materials used are sheet steel, copper, polycarbonate, ceramics and epoxy resin. For the adequate insulation of the live parts inside normal dry air under atmospheric conditions is used. The main copper parts are dimensioned in such a way that an optimum has been reached between the amount of raw materials used and the watt-losses during normal use of the switchgear. The major difference between standard SF$_6$ designs and the Xiria design to be considered is the higher amount of raw material depletion, but epoxy resin as used in electrical equipment is always combined with 60% silicium (sand) as a natural filling material, which brings this consideration in another perspective. Unwanted emission of SF$_6$ gas could occur at several places due to the necessary handling and system leakage and could be very difficult to control on a worldwide scale. Due to the fact that epoxy resin is a fully inert material, it can be crushed and used as a filling material, even together with other types of solid insulating material.

**Maximum safety**

The Xiria unit has been designed with the operator in mind. Internal faults are prevented by using a fully insulated design where the latest technologies are used to insulate each phase within the enclosure, leading to very compact and safe switchgear. Switching is done by using proven technology with compact vacuum interrupters for the load break switch panels and the circuit breaker panels. All operations are interlocked. The mechanical position of the integrated disconnector in the unit is clearly visible via the viewing windows at the front, so no mistake can be made during switching.

![Fig.5: safe switching sequence](image)

**CONCLUSIONS:**

- Market driven changes will result in higher power quality/reliability demands, against no or minimal extra lifetime costs of the equipment, achieved in the described unit by its increased availability. Also the price of non-availability of energy in the distribution network will increase.
- A better control of the network is contributing to the quality of the network if the majority of RMUs is equipped with intelligence and communication devices. This will be made possible in the near future because prices of protection and communication devices related to their functionality continue to decrease.
- Avoiding the use of environmentally suspected materials. The design of switchgear units with the "fit and forget" principle leads to environmentally and economically acceptable solutions.
- The Holec Xiria RMU is fit for the future, and completely in line with the international IEC standards, like the IEC 60298 and even with its revision which can be expected soon to come out.

**REFERENCES:**
[1] UNIPEDE, "Quality of service and its cost", final report of group of experts on economical aspects of quality of service (presented at 22nd UNIPEDE-Congress, Copenhagen, 1991)


