Both technology and market driven changes are taking place in electricity networks worldwide, resulting in a new philosophy for future MV networks and new design aspects for the switchgear itself. This paper describes the design and the main specifications of a new generation of indoor MV switchgear.

Innovative ring main unit design for safety and availability

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Besides the evolution in switchgear design, there is also an ongoing evolution in the international standardisation field. For the subject of this paper, the new IEC 62271-200 standard for metal enclosed switchgear plays an important role. This revised standard addresses modern switchgear designs, like fixed circuit-breaker systems similar to conventional systems (with drawable breaker designs). Another important topic is internal arc classification and the definitions for compartmented, metal clad and cubicle, and the thoughts behind these definitions concerning safety and availability.

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

Today’s layout of MV cable networks

The distribution network is principally ring shaped, and is operated radially (in open rings). This creates an (n-1) redundancy in the structure, but not in the mode of operation. At the beginning of the open ring, a circuit breaker is placed in the feeding substation (see Fig. 2). 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 MV (3 - 20 kV) networks are the cause of more than 75% of the approximately 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, an LV customer in the Netherlands is without electricity supply once per four years 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 proved 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 industrialised world.

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

- A review of labour costs and labour structure
- A critical review of investments in the network

A change in the perception of electricity as a right to that of a commercial product.

Liberalisation has affected the industry structure and processes in the following areas:

- Less vertical integration between the supply chain of generation, transport and distribution
- A review of cross subsidies within the
Less time will be spent on maintenance, and "clean and green" type of power will be a very high degree of reliability. Evolution results in a higher availability due to the necessity of cost reduction, which is essential over the total lifecycle of the equipment. The liabilities of distribution companies will increase, so there will be a greater need for information about energy consumption. Normal operational activities will however be done by less skilled (meaning less expensive) operators due to the necessity of cost reduction, which is essential over the total lifecycle of the equipment. The liabilities of distribution companies will increase, so the insurance of their risks will become more important too.

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

Environmental issues
The influence of environmental issues is still growing, possibly leading to next generation switchgear containing environmentally friendly materials only. This switchgear should also be able to be collected and dismantled in a safe way at the end of its lifetime. A "clean and green" type of power will be demanded in future, and this trend can be seen at an industrial level (triggered by legislation on the maximum amount of CO₂, SF₆ and other gases in the atmosphere).

From a technical point of view, there will be:
- Increasing load on the electricity grid.
- Widespread use of dispersed generation.
- The introduction of simple, economical vacuum circuit breakers that are maintenance free.
- Simple and safe operation.
- Optimisation of load flow.
- Low maintenance, or, even better, maintenance free switchgear.
- Compact designs, but not too compact - proper handling must still be possible.
- Green and clean design, with easy end of life handling.
- Steadily reducing costs for intelligence, sensors and communication.

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

Double busbar systems also have their origin in the then need for maximum availability (the other drivers 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 ensures that the switchgear can remain in service.

Switching in vacuum
Within the industry, 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 contained within the "sealed for life" MV switchgear described (Fig. 3).

Circuit breakers instead of fuses
A logical step in the design of the new ring main switchgear was to replace the relatively bulky and expensive HV fuses by a circuit breaker (CB) to protect the transformer (Fig. 4). This has, among other things, the following advantages [5, 6]:
- Losses reduced to about 5% compared to that of fuses.
- No limitation in current ratings for the settings of the protection.
- Interruption of all possible currents, including those characteristic of evolving faults.
- Possibility of fitting with protection systems, which are independent of external power, having close discrimination with the LV fuses.
- No stockholding necessary for various types of fuses, thus minimising the risk of mistakes.
- Suitability for remote restoration of the network supply.
- Increased safety: the live MV internal parts of the switchgear don't have to be touched when changing the settings of the protection or restoring supply after a fault.
- Reduced maintenance: the live MV internal parts of the switchgear can be fully sealed, as there is no need for access to primary parts such as fuses, thus avoiding deterioration due to ingress of moisture and dust.

A possible drawback of CBs compared to fuses, is that there is no (peak) current limitation. However, 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 an important factor.

Many companies have already made a cost comparison considering 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 Xinia ring main unit is provided with a newly designed and optimised electronic protection device that is kept simple and economic. The design has focussed on 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 better selectivity for nearly the same costs. The relay needs no external power supply, but is energised 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°C.

Some aspects of the specification...
Environmental design

The environmental impact of human activities has become a great - and often justified - concern in most countries. It has recently focused on potential climatic changes due to the increase of greenhouse gases in the atmosphere. One of these (man-made) gases is SF₆, 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 SF₆ production) [8,9]. In Xiria ring main unit, however, the main construction materials used are sheet steel, copper, polycarbonate, ceramics and epoxy resin. For 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 balance 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 SF₆ designs and the Xiria design is the higher amount of raw material depletion in the case of SF₆ designs. Unwanted emission of SF₆ gas can occur at several places, and system leakage is 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

This ring main 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 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.

Earthing is achieved in the unit by changing from the service position (Fig. 5-1) to the OFF position of the vacuum interrupter (Fig. 5-2), moving the disconnector to the earthed position (Fig. 5-3), and closing the vacuum interrupter again (Fig. 5-4). Following this sequence, the earth connection is switched on to the cable via the vacuum interrupter. This is a safe way of earthing, even under fault conditions, because the interrupter has been designed to close on to a short circuit current.

Conclusions

Market driven changes will result in higher power quality/reliability demands, with no (or minimal) extra life-time costs of the equipment. The price of non-availability of supply of energy in the distribution network will increase. The new ring main unit described achieves these demands by its increased availability.

Better control of the network contributes to the quality of the network if the majority of RMUs are equipped with intelligence and communication devices. This will be made possible in the near future as prices of protection and communication devices continue to decrease relative to their functionality.

Avoiding the use of environmentally suspect materials, enables a “fit and forget” principle to the design of new switchgear, and leads to environmentally and economically acceptable solutions.

References


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