HRC FUSES - MAJOR DESIGN COMPONENTS FOR LOW VOLTAGE DISTRIBUTION SYSTEMS

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1 Introduction

Low voltage high breaking capacity fuses according to IEC 269-2-1 section (NH fuses) represent the most important switching and protective devices in low voltage distribution systems of German power utilities. Their application ranges from LV distribution boards of transformer substations to cable distribution cabinets and customer fuse-units, the takeover points between power utilities and customers. The technical requirements for electrical fuses in LV distribution systems may be listed under three major groups:

- electrical performance
- operational behaviour
- design component.

Research work and international standardization in the field of electrical fuses have primarily dealt with their physical effects, electrical performance and operational behaviour. Not very much attention was paid to their function as design components for LV substration cable distribution boards, in spite of the fact that the user benefits and consequently the competitiveness of fuse systems depend very much upon this function. Looking closer at problems related to fuse adaption to switchgear designs, the fuse-base appears to obviously of gaining importance as the essential link to the switchboard. In the literature and international standards, however, fuse-bases are hardly mentioned and the physical integration of HRC fuses in their technical environment has not been a major issue so far. On the occasion of a poll conducted within major European and North American countries by IEC SC 32B, which was aimed to determine the most important features of a potential worldwide unified fuse system, out of the ten top ranked attributes, five each were related to electrical performance and operational behaviour respectively. Design features were given low priority /1/2.

Electrical function and performance of the NH system, however, have reached a high level of user satisfaction in various respects, such as

- reliable protection of cables, lines and equipment against short-circuit and - if need be - overload currents
- discriminating disconnection of defective lines or devices
- tailor-made characteristics for protection of almost any apparatus and systems
- limitation of dynamic short-circuit currents on a high level of breaking capacity
- minimum power dissipation
- reliable function without aging or the need for maintenance work.

After more than a hundred years of development work in this field, the state of the art can be deemed to have reached maturity, i. e. major progress in functionality of electrical fuses cannot be expected in the foreseeable future. In order to strengthen the competitiveness of fuses over other protective devices, the focus of development and - if need be - standardization work has to be directed towards application, primarily design improvement of distribution boards and additional benefits for the network operator. The authors believe that on the basis of standardized fuse-links, specially designed fuse-bases and where applicable fuse-carriers may offer a variety of additional functions to the installer and operator of low voltage distribution systems. By means of the example of specific features of the NH system according to IEC Publ. 269-2-1 Section I "Fuses with fuse-links with blade contacts" /3/, the authors explain some of the useful additional functions fuses may exhibit in LV distribution systems.

2 Paramount Features of the NH System

2.1 NH Fuse-Links

NH fuse-links exhibit in addition to the electrical properties described in IEC 269-1 and IEC 269-2-1 some special properties that can be used for improved network operation and switchgear design in low voltage distribution networks. One of them is the fact that all fuse-links of one size are interchangeable independent of their rated currents, utilization category or rated voltage. Thus, an existing LV distribution board may easily be adopted to the electric devices or network components to be protected. The distribution board may be designed and built based on the expected total load without knowing all the details of later use. The adoption of the NH fuses to the individual components to be protected and if need be limitation of the load is simply done by insertion of the proper fuse-link into the outgoing circuit.

NH fuses have been known and used in Germany since about 1920. The variety of products and their quality have continuously been improved according to users' needs: consequently all technical requirements were stipulated by users' needs and layed down in the German standard VDE 0636 /4/ which exceeds IEC 269-2-1 considerably. A major advantage of this standard-family is the great number of available utilization categories and current ratings of each fuse size. Table 1 gives an overview of the NH fuse-links made according to VDE 0636 and available in the market: A number of additional utilization categories and current ratings that are not contained in IEC 269-2-1. Fuse-links with rated voltages of 690 V, 500 V and 400 V are available in the same dimensions. In addition, VDE 0636 standardizes fuse-links for 1000 V rated voltage.

Table 1- Range of Current Ratings and Utilization Categories of NH Fuse-Links

Size	Utilization category according to VDE 0636						
	part 21 gL/gG	part 22 gTr	part 22gB	part 23 gR	part 23 aR	part 22 aM	solid link
00	2 - 160 A	-/-	16 - 125 A	16 - 160 A	80 - 160 A	16 - 100 A	250 A
0	6 - 160 A	-/-	25 - 160 A	35 - 160 A	32 - 160 A	-/-	250 A
1	6 - 250 A	-/-	16 - 250 A	35 - 250 A	32 - 250 A	25 - 250 A	400 A
2	25 - 400 A	50 - 250 kVA	16 - 400 A	80 - 400 A	160 - 400 A	80 - 400 A	630 A
3	315 - 630 A	50 - 400 kVA	-/-	315 - 630 A	315 - 630 A	125 - 630 A	1000 A
4 a	500 -1600 A	50 - 1000 kVA	-/-	-/-	-/-	315 - 1250 A	2500 A

2.1.1 Utilization Categories

VDE utilization categorie "gL" corresponds to "gG" of the international standard IEC 269-2-1. There are, however, more severe requirements to be fullfilled with respect to low overcurrent interruption: For utilization "gL" an additional breaking capacity test has to be passed with the fusing current I_f at full recovery voltage.

Utilization category "gTr" has specifically been developed for overload protection of distribution transformers in order to allow for economic transformer load. These fuse-links acc. to VDE 0636/22 provide discrimination to the up-stream high voltage fuses as well as to the down-stream fuses for the outgoing cables.

Utilization category "gB" is designed for cable and line protection in the mining industrie and is especially insensitive to in-rush currents of electric motors. In addition they meet aggravated test requirements concerning breaking capacity test.

Among the fuses for semiconductor protection, VDE 0636/23 defines in addition to "aR" fuse-links as known from IEC 269-4 full breaking range fuse-links of the utilization category "gR". The utilization categories "aR" and "aM" are identical to the corresponding IEC-types. As a rule their breaking capacity is however at least 120 kA.

In case there is no circuit protection needed, a solid link may be used instead of the fuse-link and provide a point of line isolation. Solid links provide greater current carrying capacity to the fuse-base and are therefore mainly used in busbar feeder units.

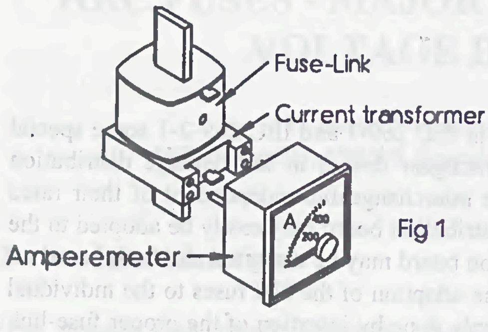

Fig. 1 - C. t. combination unit

Aside of the various fuse-links shown in table 1, there is a number of special links available which can be used instead of standard fuse-links, e. g. current transformer combination units (Fig. 1). C. t. combination units consist of a NH fuse-link with a c. t. mounted on the blade contact. Both the fuse-link and the c. t. have one gripping lug each and the combination unit can be installed in the place of a regular size NH fuse-link. Earthing and short-circuiting devices in the standard dimensions of NH fuse-links can also be inserted into the fuse-bases for safe working conditions. Insulating links are available for protection against inadvertent energizing of disconnected circuits.

Because of their generally high breaking capacity, NH fuses of different sizes and extremly different current ratings may be installed on the same busbar system up to prospective short-circuit currents of 100 kA and above.

2.1.2 Design Features

One of the most useful design features of NH fuse-links is the solid 6 mm blade contact made of silver plated copper or copper alloy. They do not only provide excellent permanent electrical contact and allow for easy fuse-link replacement but are also suitable moving contacts for switching operations, as shown in 3.2.1. Arc erosion of the solid material and deterioration of the contact surface is kept within acceptable limits.

Sometimes even minor details may provide significant benefits to the network operator, e. g. blown fuse indicators that ease identification of interrupted circuits are mandatory for NH fuse-links. Geometry and material allow for an indicator placed preferably in the front center where visibility is best.

Insulated gripping lugs are mentioned in IEC 269-2-1 but not really specified as such. They are supposed to provide protection against accidental access to live parts. The German standard for NH fuse-links, VDE 0636/21 defines test requirements concerning insulation, mechanical and thermal endurance of insulated gripping lugs that ensure a high level of workers' safety.

2.2 NH Fuse-Holders in Low Voltage Cable Distribution Boards

A paramount feature of the NH fuse-base is the spring-loaded silver-plated copper jaws that receive the 6 mm blade contacts. According to table IV of IEC 269-1, silver-plated copper contacts are not subject to a temperature rise limit other than the necessity of not causing any damage to adjacent parts. All other sorts of contacts have to respect the temperature limits as given in table IV.

The contacts of the NH system make fuse-link replacement very easy even when live or under load. For improved workers' safety the contacts may be covered with insulating covers, that compliment the insulating gripping lugs as mentioned above to a high level of protection against accidental access to live parts.

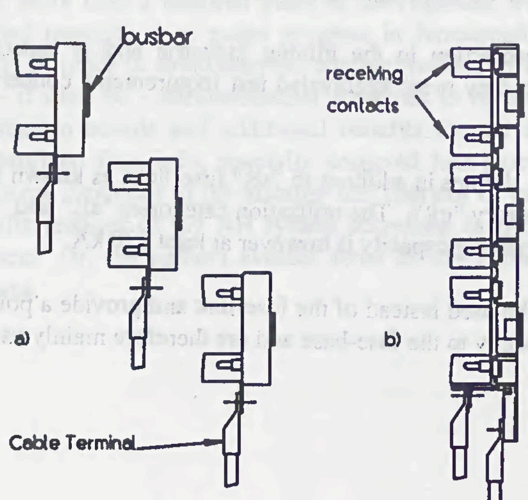

Fig. 2

The development of 3-phase units of NH fuse-bases for direct busbar mounting (Fig. 2a) in Germany reduced the assembly effort and the dimensions of LV fuse-boards significantly. Fuse-rails as shown in Fig. 2b consist of three vertically arranged fuse-bases for 3-phase circuits and have integrated cross-bars to the terminals outside the busbar area. Thus, an even more space saving busbar arrangement in one plane can be achieved. Fuse-rails additionally give the LV distribution boards a very clear appearance for easy identification of the individual outgoing circuits.

Fig. 2 - NH fuse-bases for direct busbar mounting
a) Single-phase fuse-bases
b) three-phase fuse-bases (fuse-rails)

As mentioned before, NH fuse-links may be operated by means of a replacement handle under load conditions as occur in the LV distribution network of power utilities. The operational performance may further be increased by special contact design or additional arc quenching devices. There have also fuse-bases and fuse-rails been developed with integrated fuse-carriers (Fig. 3) that allow even less skilled persons to safely operate these devices. The switching capacity of these devices exceeds the necessities of power utilities and makes them suitable for industrial use with higher rated currents, higher rated voltages and power factors as occur in motor circuits. These devices meet the requirements of the fuse standard IEC 269-2-1 as well as the standard for fuse combination units IEC 947-3 /5/.

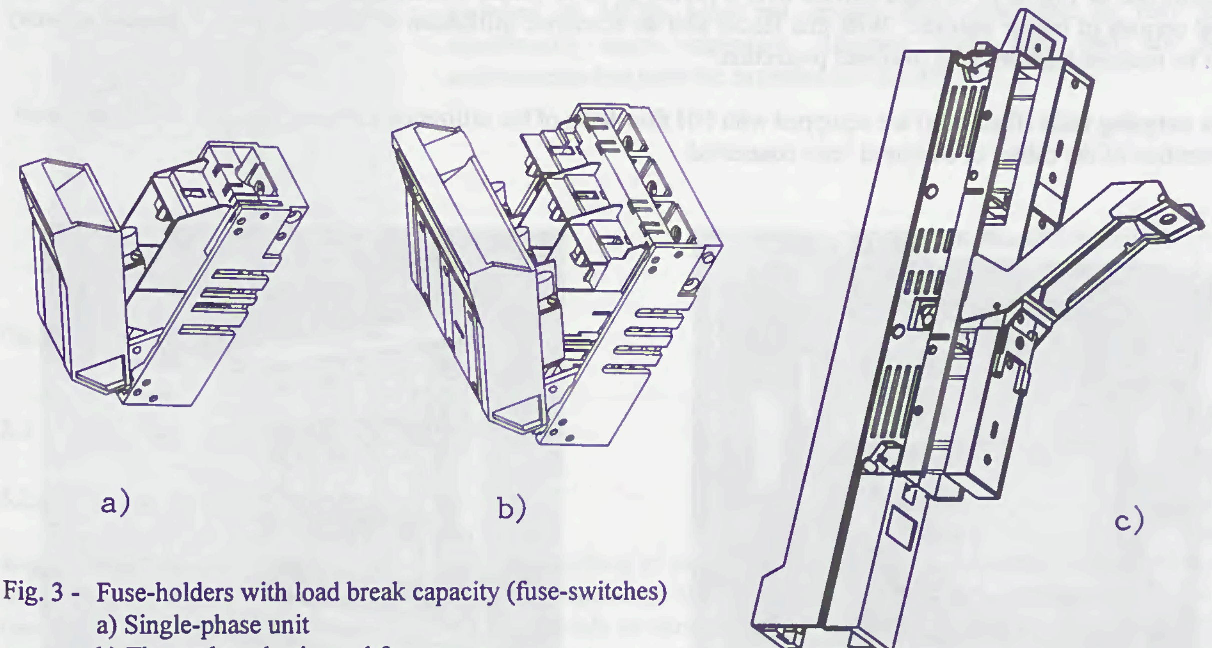

Fig. 3 - Fuse-holders with load break capacity (fuse-switches)
a) Single-phase unit
b) Three-phase horizontal fuse arrangement
c) Three-phase vertical fuse arrangement

3 NH Fuses - Major Switching and Protective Device in Power Utility Distribution Systems

3.1 Places of Use of NH Fuses in Distribution Systems

3.1.1 Architecture of German Power Utility LV-Networks

The majority of private housholds and small business customers are supplied with electrical energy via the 400 V 3-phase distribution network of public power utilities. For that reason the LV-network expands over the whole country, is heavily branched and consists of huge lengths of cables and overhead lines. The necessity to have full control over this very complex network and to provide cost efficient service has led to mashed network configurations or open rings operated as radial networks. Networks in areas with very low power consumption or concentrated load (residential areas with electric storage heaters) are sometimes designed purely radially. In case of a breakdown, the faulty line can be disconnected easily and the remainder of the network step by step reenergized. Individual lines can also be isolated for construction work.

As the continuity of electric power is the major target of distribution network operation, all network components have to be selected thoroughly with respect to reliability of function, ease of assembly, easy adaptability to local load conditions. They should also be maintenance free and of safe design.

NH fuses have therefore been selected by German power utilities as protective, isolating and switching devices in the LV distribution network. They enable a very simple and economic design of LV distribution boards in the transformer substations as well as in cable distribution cabinets and house connection boxes.

3.1.2. LV Distribution Board in Transformer Substations

Transformer substations represent the link between regional MV and the local LV system. The LV distribution board contains as a rule a 3-phase busbar system with 6 to 8 outgoing circuits having rated currents up to 400 A (Fig. 4). The utilization of fuse-rails as standardized in DIN 43623 /6/ leads to a very compact, cost efficient, easy to install and clear arrangement of the outgoing units. The incoming unit consists of an NH fuse-switch disconnector equipped with fuse-links of the utilization category "gTr". The "gTr"-fuse-links allow to run the transformer at 130 % of its rated current over a period of 10 h, which is sufficiently long to cover the daily high-load periods of power utilities. With this feeder unit an economic utilization of the transformers thermal capacity can be realized together with overload protection.

The outgoing units (fuse-rails) are equipped with NH fuse-links of the utilization category "gL/gG" for short-circuit protection of the cables or overhead lines connected.

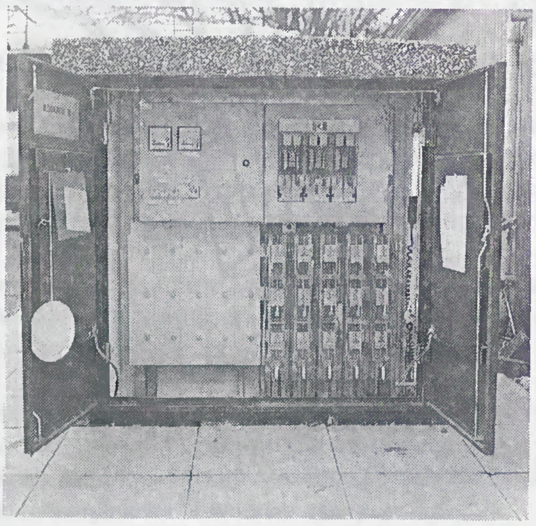

Fig. 4 - LV-distribution board in a compact 630 kVA transformer substation, 1 feeder, 5 outgoing circuits

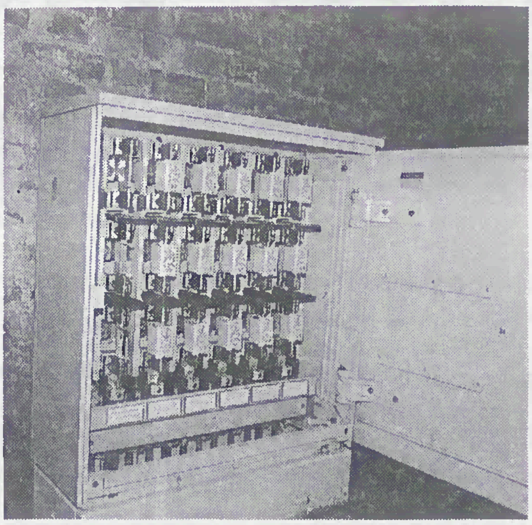

Fig. 5 - Cable distribution cabinet

3.1.3 Cable Distribution Cabinets

Cable distribution cabinets (CDC) form the knots of the LV distribution network. They are also used for switching and isolating of the connected lines. CDCs contain an installation similar to the LV compartment of transformer substations (Fig. 5). Fuse-rails mounted on 3-phase busbars, equipped with "gL/gG"-fuse-links are used for connection and protection of the individual branches. The outgoing cables and overhead lines have to be protected against short-circuit currents including those generated by faults at the end of the line. The high breaking capability of NH fuse-links at low short-circuit currents or high overcurrents respectively is therefore of significant importance in expanded networks.

In many cases additional circuits will have to be connected to the CDC busbars without interruption of the supply to existing customers. NH fuse-rails have been designed for safe installation on live busbar systems and do therefore not have to be installed in advance when the further development of power consumption is not known yet.

3.1.4 Fuse-Units for Private Homes

Service lines to private homes and small business customers are generally connected to the main supply cable by branch joints without fuses. Short-circuit protection of the branch cable is provided by the upstream fuse-link in the CDC. According to German wiring regulations VDE 0100/732 /7/, supply cables and lines entering homes need to be protected against overheating because of the fire hazard. This mandatory overcurrent protection as well as the protection of the supply network from faults in the customers installation is performed by NH Fuse-links of the utilization category "gL/gG" installed in a sealed fuse-unit (Fig. 6). The fuse-bases inside the fuse-unit represent the take-over point between the power utilitiy's distribution network and the consumer's installation.

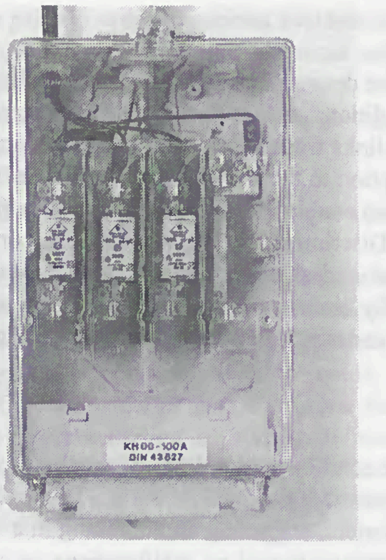

Fig. 6 - Fuse-unit for private homes

The network operators may remove the fuse-links of the fuse-unit in order to isolate the home installation from the supply system e. g., to prevent damage of electronic equipment or household appliances when high voltage is applied to the supply cable for fault location.

The great number of fuse-units in the field requires a very dependable and absolutely maintenance-free protective, switching and isolating system which has been found in the NH fuse-system. Mechanical switches or MCBs have not proven their suitability as they are significantly more expensive, dissipate more heat and are not maintenance-free over the expected service live.

3.2 System Operation with NH Fuses

3.2.1 Load Current Switching

Regular switching operations, such as off and on switching of cable and overhead lines or customer main entrances are performed by removal or insertion of the corresponding NH fuse-links. Switching operations up to 400 V operating voltage and 400 A operating current can safely be carried out by skilled power utility operators using the standardized replacement handle and personnel protection means. Even making on a high fault is possible and does not expose the operators to danger. This practice is limited to the service conditions of the LV distribution network including a relatively high power factor. Currents above 400 A and lower power factors, e. g. feeder units of the LV busbar in transformer substation, will also be switched by means of NH fuse-links but fuse-bases with integrated fuse-carriers, e. g. fuse-switches and fuse-switch-rails, will be used. The utilization of NH fuse-link as moving part for switching operations offers a great number of switching and isolating points in the distribution network at low costs and enables the power utilities to sectionalize very small units of their LV distribution network.

When the fuse-links are removed, the fuse-bases form an easy visible and safe isolating distance. Insulating inserts, if need be with a danger notice, may be used to prevent unauthorized reenergizing of systems when people are at work. The fuse-bases can also be used for cross-connecting and earthing of a three-phase circuit.

3.2.2 Short-Circuit Protection

The prospective short-circuit currents in LV distribution networks have been continuously increasing and exceed in most places the level of 25 kA. In congested areas the prospective short-circuit current may reach significantly higher levels. The power utilities have opted for current limiting fuses rather than circuit breakers as the thermal and dynamic stability of network components, which means capital investment can be kept on a much lower level.

3.2.3. Interruption of Overload Currents

While high short-circuit currents do not represent a major problem for power-fuses (the breaking capacity of NH fuse-links typically exceeds 100 kA), the interruption of lower level fault currents or overload currents may represent a problem to some fuse-systems. NH fuse-links of the utilization category gL have to pass the fusing current test at full recovery voltage. This test duty is related to the smallest short-circuit current generated by faults at the end of a line, that needs to be interrupted by the fuse. Overload protection of underground cables and overhead lines is usually not necessary as human lifes and private property will not be endangered (with the exception of home supplies as mentioned under 3.1.4). The interruption of temporary overloads is anyhow not desired as the power utilities are very much interested to keep the system in service during the periods of maximum energy consumption or in emergency cases.

3.2.4 Discrimination

The radial architecture of LV distribution networks contains several protective devices in series. They have all to be coordinated so that correct discrimination is achieved under all fault conditions and only the nearest protective device should clear the fault. The network protection by means of NH fuse-links from the transformer substation to the customers fuse-unit ensures proper discrimination and limits the interruption to the faulty circuit. NH fuse-links are available in a broad range of current ratings in each size and do therefore enable very fine discrimination from the transformer substation down to the CDCs and the customer fuse-units. Discrimination is given between current ratios of 1:1.6 over the entire operation characteristic, i. e. under overload and short circuit conditions. Proper selection of the gL-fuse-links in series by their rated current, limits the faulty circuit and service interruption to an absolute minimum and gives optimum utilization of the thermal capacity of underground cables and overhead lines.

3.2.5 Additional Features

NH fuses as protective and switching devices in the LV distribution network combine a high level of reliability with a minimum of maintenance effort as they do not contain any complicated movable mechanical parts. The melting element of the fuse-link integrates the functions of current and time measurement, triggering and breaking in a very simple matter. There is no sophisticated parameter setting or calibration necessary and no malfunctions or other problems may occur by mechanical wear or fatigue of materials as are quite common with circuit-breakers.

The low power dissipation of NH fuse-links compared with circuit breakers enables small dimensions of customer fuse-units and CDCs and avoids thermal problems even at high operating currents.

The power utilities use the interchangeability of NH fuse-links by rated current for adoption to changing local load conditions or for changes in the network configuration.

Last but not least it has to be mentioned that disposal of NH fuse-links after operation has not been a problem and is not expected to be one in the future. Operated NH fuse-links may be disposed like ordinary household waste but under environmental aspects the recovery of noble metals in a converter process as used by copper refineries seems to be advisable. The residual mineral components contained in NH fuse-links are suitable materials for road paving.

The presently high level of technical requirements and product quality of NH fuses goes back to a German power utility initiatives of more than 30 years ago when the important criteria for fuses in power utility distribution systems were laid down in a German standard. Major subjects of this standard formed part of the international and European fuse standard. The VDE mark usually restricted to consumer products has also been implemented for fuse-links in order to ensure a consistantly high level of quality by third party certification and product survey. NH fuse-links have therefore become a very cost efficient component for the public power utility distribution network and since proven their longterm reliability.

3.3 Workers's Safety Aspects

3.3.1 Safety Rules for Switching Operations

The replacement of current carrying NH fuse-links follows the rules of work carried out on live parts. Withdrawal and insertion of NH fuse-links in an open type assembly without protection against direct access to live parts and without any specific arc quenching means is not considered dangerous, providing certain conditions and rules are adhered to. The operator has to make use of standardized replacement handles with integrated leather sleeves and has to wear a safety hat with protective screen. Distribution boards in the LV system of power utilities are as a rule of the open-type assembly, the operation and specifically replacement of NH fuse-links is therefore reserved to trained electricians or to operators instructed in electrotechnical matters. They are authorized to withdraw and insert NH fuse-links under regular operating voltages up to 400 V and operating currents up to 400 A. Making on a high fault is also possible because of the current limiting characteristics of the fuse-links and does not represent a major risk. Switching of currents and voltages that exceed the above mentioned limits is also possible if the fuse-links are operated by means of fuse-carriers that are integral parts of the fuse-holders. Additional means for better control of the arc energy (arc quenching devices) may be needed.

Existing distribution boards with empty spaces on the busbars may be completed by additional fuse-rails without disconnection of the busbar system. The connection of additional outgoing cables is also possible without service interruption of existing circuits. Before working on a live system, insulating covers have to be applied to adjacent.

live parts in order to prevent accidential access. Insulating tools as well as suitable body protection means have to be used. Aside from the technical safety devices and rules, there are clear operating instructions and a clear organization structure is necessary, too. That means the design of low voltage distribution boards and the organization of the staff have to go together. Under these conditions work on live systems can be done on a high level of safety.

3.3.2 Installation in closed operating rooms

There is no permanent protection against access to live parts needed for distribution boards inside customer fuse-units, CDCs and transformer substations. The protection required by safety rules is provided by their location inside locked operating rooms. By organization directions it is ensured that specifically trained and instructed operators only may have access to these rooms. The utilization of uniform design criteria for transformer substations and CDCs over extended periods of time ensures uniform and well known working conditions throughout the network. The implementation of additional insulating covers or encapsulations in distribution boards or on individual components is partially possible but includes the risk of mistakes as the operators have to identify the actual type of distribution and level of protection and act accordingly.

Under extremely narrow conditions, NH fuse-boards may be equipped with contact covers and insulated gripping-lugs for better protection against direct access to live parts. The open type assembly is however the preferably used type of NH fuse-board. It has proven its suitability in operating practice and represents the generally accepted state of the art of German power utilities.

4 NH Fuse-Boards for Industrial Use

Low voltage distribution boards in the industry are usually not located in separate operating rooms where unauthorized access may be excluded, but in easily accessible locations. Fuses and fuse-switches are therefore installed behind locked steel-doors. The operating personnel does usually not exhibit the same level of skill in switching and handling of NH fuse-links as the power utility staff. This is a major reason for why the industry prefers NH fuse combination-units with integrated fuse-carriers which do not need a replacement handle for operation. The three-pole fuse-rail design is preferably used for the sake of efficiency in space consumption and clearness of the arrangement of outgoing circuits in large size distribution boards. Fig. 7 shows an arrangement of fuse-switch-rails for dependent manual operation and fig. 8 withdrawable switch-fuse-rails for independent manual switching operation. One of the most important features of these NH fuse-combination units is isolation of electric circuits and equipment for maintenance and repair work. For this purpose the actuators of these devices can be locked in either connected or isolated position by means of several padlocks in order to prevent unauthorized switching operations.

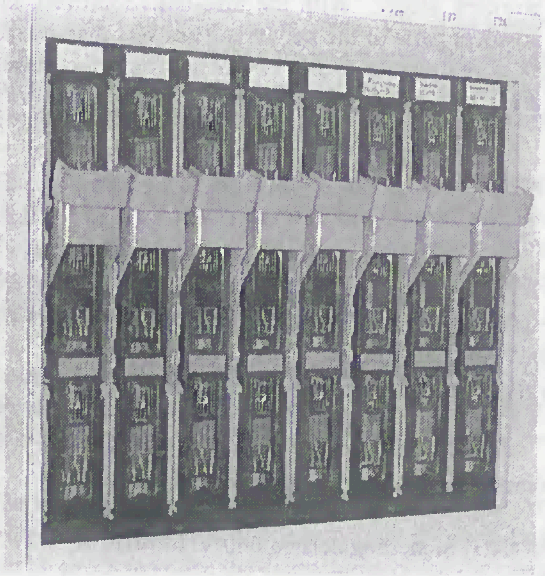

Fig. 7 - Industrial switchboard with fuse-switch-disconnectors

Fig. 8 - Industrial switchboard with switch-disconnector-fuses

Distribution boards with fuse-switch-rails are usually of the enclosed assembly type, whereas switch-fuse-rails are used in dead front assemblies with accessible actuators. They are suited for more frequent switching including motor-switching by unskilled persons. Due to the withdrawable design, switch-fuse-rails can be exchanged without deenergizing of the busbars, that means without interruption of other equipment of the same distribution board. NH fuse-combination units have been basically designed to be used in dead-front assemblies or enclosed assemblies with a minimum IP2X degree of protection against direct contact and typically IP3X.

In industrial distribution boards remote indication of blown fuses is very often needed in order to identify the defect circuit or equipment immediately and initiate corrective actions with no time delay. For that reason fuse combination-units are equipped with electronic or electro-mechanical blown fuse indicating devices that signalize via a micro-switch wheather a fuse and which fuse has blown. Additional micro-switches may be used to indicate the I/O-position of the switch or whether a fuse-link is present or not.

5 Conclusions

On the basis of standardized fuse-links, specifically designed fuse-bases and -where applicable- fuse-carriers may offer a variety of additional functions to the installer and operator of LV distribution systems, e. g.

- compact sized and clearly arranged distribution panels,
- less assembly effort,
- uniform components,
- adaptability to load circuits,
- sectionalizing and isolating function,
- load-break function.

By means of the example of specific design features of the NH system according to IEC Publ. 269-2-1 Section I "Fuses with Blade Contacts", the authors explain some of the useful additional features fuses may exhibit in LV distribution systems. Triple fuse-bases for installation on copper busbars of a 3-phase system (fuse-rails) have shown to be very efficient in space consumption, installation effort and clearness of the arrangement of distribution panels.

The generally high breaking capacity of NH fuse-links enables side-by-side installation of low and high rated current circuits on high-power busbar systems. As NH fuse-links are interchangeable by rated current, rated voltage and utilization category the distribution panels are very flexible in use even after installation. Increasing load or changing equipment, in most cases requires the replacement of fuse-links only and no modification of the panel.

The nature of NH blade-contacts made of solid copper or brass allows for load-break operations. Clear operating instructions for work with NH fuses allow for a high level of workers' safety. With the fuse-links removed, the fuse-base represents an easily visible isolating distance between adjacent parts of the network. Thus NH fuse-panels offer a great number of possibilities to sectionalize a LV network at reasonable costs. Power interruptions caused by faults or maintenance work may thus be limited to small areas and the continuity and reliability of service increased in an economic way.

/1/ IEC SC 32B (Sec) 198 "Enquiry: Survey to evaluate an order of importance of the attributes of fuse-systems"

/2/ IEC SC 32B (Sec) 113 "Results of enquiry on 32 B (Secretariat) 198"

/3/ IEC Publication 269-2-1: 1987 "Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial applications)"

/4/ Deutsche Norm VDE 0636 "Niederspannungssicherungen"

/5/ IEC Publication 947-3: 1990 "Low-voltage switchgear and controlgear; switches, disconnectors, switch-disconnectors and fuse-combination units."

/6/ Deutsche Norm DIN 43623 "Niederspannungs-Hochleistungs- (NH) Sicherungsleisten 660 V 100-630 A, Mai 1981"

/7/ Deutsche Norm VDE 0100 Teil 732 "Hausanschlüsse in öffentlichen Kabelnetzen"