A STANDARD FOR MEDIUM-VOLTAGE CABLE SYSTEMS IN ESKOM DISTRIBUTION

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SYNOPSIS

This paper deals with some of the design philosophies that are unique to the Eskom Distribution Standard for medium-voltage cable systems i.e. SCSASABL6, *General information and requirements for medium-voltage cable systems* [1]. The intention of this paper is not to address every design requirement for a medium-voltage (MV) cable standard but rather to focus on those that are often overlooked.

BACKGROUND

Over the years the Eskom Distribution business has consisted of a number of regions, the boundaries of which were determined by the provincial boundaries of the country at the time. In the past twenty years the business has been through a complete cycle of decentralisation and then since 1990 - centralisation. In the late 1980's the regions were autonomous with regards to business practices. The result of this was the creation of standards and specifications by each region that were suitable to the specific requirements of that region. Purchasing of equipment was also handled on a regional level. Although there were technical special interest groups that met to share experiences and ideas there was no drive to have a common national distribution standard.

In 1990 Eskom Distribution committed to the government driven "Electricity for all" project and all regions were contributing to meet the target of 300 000 customer connections per year. It was soon very clear that there was a need for a national standard for low cost electrification projects and that economy of scale could be achieved by having a centralised purchasing system. The "Electrification Standard" was created with input from all regions and soon after national contracts were established with various suppliers for the purchase of strategic equipment. The DTAB (Distribution Technology Advisory Board) was established which was a corporate body with regional representation that was responsible for managing the "Electrification Standard" and implementing it. By 1993 the "Electrification Standard" had grown to a document that covered more than just low cost electrification practices and included substations, urban reticulation, street lighting, survey etc. A clear omission from the "Electrification Standard" was any form of standards for high-voltage, medium-voltage and low-voltage underground cable systems. This was not seen to be a problem at the time as Eskom Distribution was predominantly seen as an overhead lines company. Furthermore the Eskom regions that were doing underground distribution had suitable regional standards in place albeit differing significantly.

In 1997 the DTAB was changed to the TESCOD (Technology Steering Committee for Distribution). TESCOD was tasked with developing a technology business plan for Distribution that would assist in achieving the overall Eskom objective of providing the lowest cost electricity. TESCOD saw national standardisation of business practices as one method of reducing cost in the business and became the driver of this philosophy. Political changes in the country resulted in Eskom regions that were not previously involved in underground distribution taking over areas with extensive cable networks. In 1997 the decision was made that national standards should be put in place for LV, MV and HV cable systems. Presently there are numerous published national standards and specifications relating to cable systems. This paper covers some of the design philosophies that are unique to the Eskom Distribution standard and relevant specifications for medium-voltage cable systems i.e. SCSASABL6, *General information and requirements for medium-voltage cable systems.*

A MEDIUM-VOLTAGE CABLE STANDARD

1. FUNDAMENTAL REQUIREMENTS

1.1 GENERAL

Advances in MV cable and accessory technology over the last 20 years has resulted in certain common practices that Eskom believed to be in-appropriate for use with locally manufactured MV equipment (e.g. compact switchgear). The equipment has not kept up with the respective technology trends making it difficult to apply a systems approach. For example, the type of cable, the equipment and the type of termination used to connect the two have become incompatible.

One of Eskom's primary objectives in compiling a standard was to look at the entire MV cable system and address the incompatibility issues that were identified – resulting in a 'system' that is comprised of components that are type tested for application together. Specifically, the following key aspects were taken into consideration:

- interfacing of MV cables with compact switchgear (i.e. for connections rated ≤ 630 A);
- interfacing of MV cables with metal-clad switchgear (i.e. for connections rated ≥ 800 A);
- impregnated paper-insulated (PILC) versus XLPE-insulated cable with reference to the compatibility of accessories at 11 kV and 22 kV;
- belted versus individually screened cable designs with reference to the SABS 0200 [2] earthing philosophy adopted by Eskom; and
- the transition from cable boxes designed to be compound filled to properly designed air-filled cable boxes used with dry type terminations.

1.2 ELECTRICAL REQUIREMENTS

The majority of South African supply authorities only have to consider the requirements for secondary distribution networks rated at 11 kV. Eskom, however, has to include the requirements for reticulation at both 11 kV and 22 kV due to:

- substantial amounts of existing 22 kV underground cable networks; and
- the fact that the majority of MV overhead reticulation is done at 22 kV and often provides the source for an underground cable network.

Eskom's earthing philosophy for MV reticulation is in accordance with SABS 0200 effectively implying that the earth fault levels are limited by the use of resistive neutral point earthing. As a result cable and accessory specifications are designed accordingly.

1.3 MECHANICAL REQUIREMENTS

The mechanical requirements for an MV cable system effectively encompass ensuring a compatible cable – equipment interface. The interface must provide adequate space for the termination of the cables required to meet the current rating while maintaining the electrical clearances. The rating of equipment in Eskom has been standardised as shown in table 1 i.e.:

Table 1 – Standard current rating of equipment

Equipment description	Current rating (Amps)
Compact switchgear and auxiliary equipment (e.g. transformers etc.)	≤ 630
Metal-clad switchgear	800
	1250
	2500

In the past, a number of failures of air-insulated metal-clad switchgear have been attributed to the switchgear supplier failing to provide a suitable cable – equipment interface. The problems have been identified as one or more of the following:

- manufacturers striving to make the switchgear as compact as possible to reduce cost and space requirements;
- switchgear designs that are based upon international practices e.g. for the termination of single-core MV cables that are relatively flexible with small overall diameters in comparison to SABS specification cable;
- the South African practice of using three-core armoured cables requiring significantly more space for terminating; and
- inadequate provision made for the termination of multiple cables per phase in order to match the respective current ratings of the switchgear panels.

Equipment rated ≤ 630 A has traditionally been supplied with various non-standard customised bushings onto which the MV cable had to be terminated. An example of this is the numerous types of bushings supplied with compact switchgear (e.g. oil-filled ring main units). This has resulted in the cable jointer having to be sufficiently skilled to cope with the various types of termination-bushing interfaces. This is believed to be an unrealistic expectation in an industry where no formal accreditation of cable jointers exists. In order to address this Eskom sought to adopt an internationally recognised and widely accepted bushing interface i.e. the EN 50181 [3] standard 630 A M16 x 2 Type C bushing. The bushing dimensions are shown in figure 1.

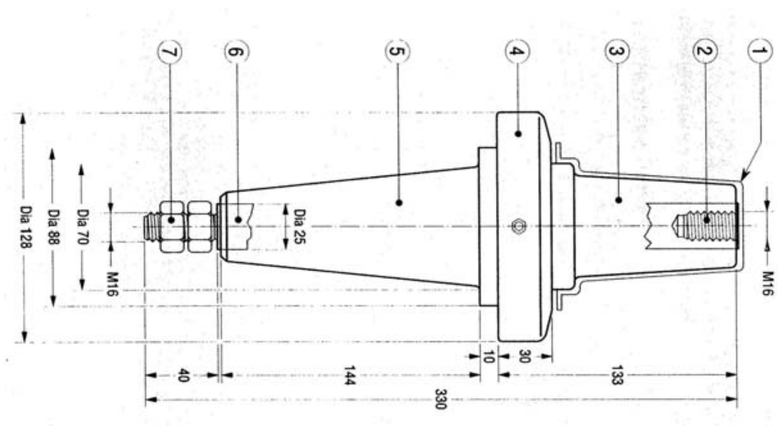

Figure 1 – 630 A Type C bushing

In addition to the non-standard bushing interface the position of the bushings relative to the incoming cable has in the past resulted in a number of problems during cable termination. This is particularly the case where large cables are terminated e.g. 185 mm^2.

Photo 1 – Oil-filled RMU bushing arrangement

Photo 2 – SF6 RMU bushing arrangement

Traditionally switchgear suppliers have provided brass wiping glands suitable for the termination of lead sheathed cables. The wiping gland provided both mechanical support and a means to connect the cable sheath to earth. With the advent of solderless earth connections (e.g. constant force springs) in modern termination kits, wiping glands are no longer required. As a result, often no cable support was provided with the equipment resulting in significant mechanical loading on the terminals or bushings. Another common problem is where the cable support provided is too close to the bushings to allow the cable to be terminated correctly.

The numerous problems experienced by Eskom with the cable-equipment interface highlighted the need to clearly define the respective types of cable terminations that could be used and the associated mechanical and electrical clearances required. In order to address this, Eskom initiated the compilation of NRS 012, *Cable terminations and live conductors within air-insulated enclosures (insulation co-ordination) for rated a.c. voltages of 7,2 kV and up to and including 36 kV* [4].

Photo 3 – Unsupported MV cables terminated into switchgear

1.4 ENVIRONMENTAL REQUIREMENTS

Air-insulated enclosures that house terminations or live conductors are not hermetically sealed and are subjected to contamination from dust and other air borne pollutants. Unlike in outdoor applications, insulation associated with equipment inside air filled enclosures does not have the benefit of natural washing from rain. Condensation in air filled enclosures is very difficult to prevent, and when it combines with pollution can lead to tracking and, in severe cases, flashover. The Eskom experience with "indoor" air-insulated enclosures in the past was that suppliers did not apply a consistent design philosophy with regards to creepage. This is illustrated in photo 4. In certain cases, insulation with specific creepages of < 10 mm/kV were found. The build-up of pollution on insulation in air filled enclosures is generally slow and failure due to insufficient creepage will occur long after the guarantee for the equipment has expired.

Photo 4 – Differing specific creepages applied in switchgear

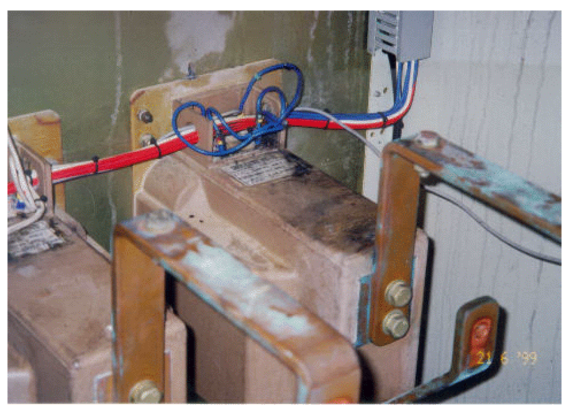

Photo 5 – Tracking on the surface (i.e. < 10 mm/kV) of a CT used in switchgear

NRS 012 specifies a minimum specific creepage of 20 mm/kV for insulation supporting live bare conductors in air-insulated enclosures. Eskom requires that insulation complies with the requirements of NRS 012 to reduce the probability of a pollution related flashovers and to minimise the maintenance requirement for these enclosures.

2. INSULATION CO-ORDINATION

2.1 SELECTION OF IMPULSE INSULATION LEVEL

SABS 1019 [5] has been adopted by Eskom for the selection of impulse insulation levels. Two impulse insulation levels are defined by SABS namely for exposed (i.e. overhead lines) and non-exposed (i.e. cable networks) installations. In Eskom, reticulation networks are often a combination of cable and overhead lines. As a result, where possible, the higher insulation level has been specified. The reality however, is that for 22 kV systems, commercially available equipment is generally not available for the higher insulation level (i.e. 150 kV). As a result attention is drawn in the Eskom standard to the application of surge arresters at 22 kV on cable connected equipment connected to overhead lines.

2.2 MINIMUM CLEARANCES IN AIR-INSULATED ENCLOSURES

Laboratory condition type testing of equipment does not guarantee that the installation in the field will meet the required insulation levels. Eskom's experience in this regard has been that the site installation often varies significantly from the type tested arrangement. This has particularly been the case in the areas of panel assembly and MV cable connections.

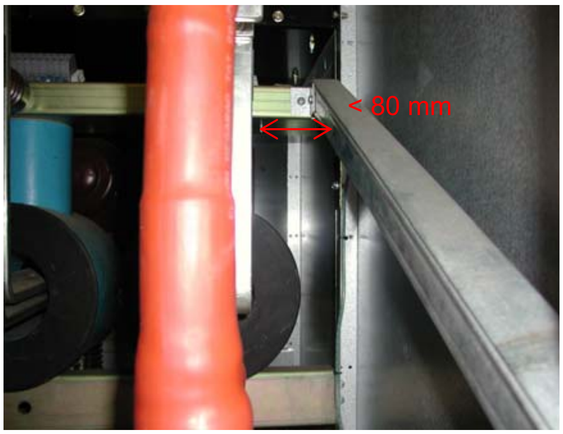

Photo 6 – Insufficient live bare metal clearance to earth

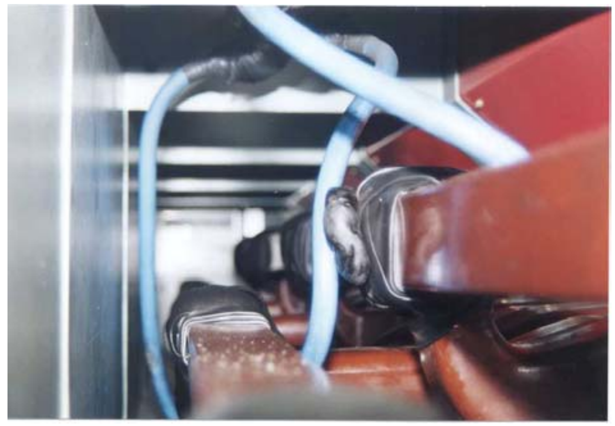

Photo 7 – Unscreened VT cables in switchgear busbar chamber

With these problems in mind NRS 012 was compiled to establish design guidelines and uniform requirements for insulation co-ordination within air-insulated enclosures. Although NRS 012 focuses on cable terminations within air-insulated enclosures, it is applicable to any live conductors within air-insulated enclosures, for example metal-clad and metal-enclosed switchgear.

The NRS 012 clearances between live bare metal, phase-to-phase and between live bare metal (i.e. a phase) and earthed metal are in accordance with the recommendations of IEC 60071-1 and IEC 60071-2 [6] for the applicable lightning impulse withstand voltage, and are based on dielectric strength considerations of the air gap.

Prior to the publication of NRS 012, the manufacturers of MV equipment paid very little attention to the minimum required clearances to be maintained between shrouded (i.e. insulated but unscreened) live metal components. Examples where this has occurred are as follows:

- unscreened single-core cables connecting the compact switchgear (e.g. ring main unit) to the transformer in mini-subs that are close to or in contact with earthed metal; and
- unscreened single-core cables connecting the voltage transformers to the busbars in metal-clad switchgear that are close to or in contact with opposing phase busbars or earth.

Due to the nature of the insulation the mistakes made in the above scenarios will not be highlighted by a short-time overvoltage test performed as a type or routine test. Instead the failure may take a number of years to occur, i.e. long after the guarantee for the equipment has expired. NRS 012 now provides the minimum requirements to be complied with to ensure long term performance of the equipment. Clearances between shrouded live metal, phase-to-phase and between shrouded live metal (i.e. a phase) and earthed metal are in accordance with the recommendations of CENELEC HD 428.2.2 S1 [7] for the applicable rated voltage. The clearances are based upon dielectric strength considerations for lightning impulse and a.c. withstand voltage (i.e. corona inception and extinction) of the air gap and solid dielectric combination.

Having stated all of the above Eskom was faced with a problem on imported compact SF6 gas-insulated switchgear. The cable box dimensions on the switchgear are accepted internationally and cannot be influenced by the relatively small local market. Eskom therefore had to ensure that suitable methods of cable termination were applied. These are as follows:

- at 22 kV, screened separable connectors (SSC's) are used. This was the primary reason behind Eskom's decision to standardise on XLPE-insulated cable and SSC's for reticulation at 22 kV; and
- at 11 kV, indoor terminations with unscreened separable connectors (USC's) are used. This option allows for the use of either XLPE or PILC cable. Although the clearances in the cable box are below those required by NRS 012 the risk is minimised by ensuring that the terminations and USC's are type tested in accordance with IEC 60055-1, IEC 60502-4 and equivalent CENELEC specifications at the reduced clearances provided in the cable boxes of this switchgear.

The publication of NRS 012 has not guaranteed implementation by the manufacturers and Eskom has had to continually ensure that the requirements of NRS 012 are consistently applied from the design stage to the final installation on site.

3. PRIMARY PLANT EQUIPMENT

The following section deals with the specific technical interventions that have been made by Eskom in order to address the requirements and problems highlighted in the previous section.

3.1 METAL-CLAD SWITCHGEAR

The traditional practice of the manufacturer supplying and installing switchgear panels is no longer common in Eskom Distribution. As a result, it is necessary to ensure that the switchgear is as "user friendly" to the contractor installing the equipment as possible. It is critical that the number of on site "surprises" are minimised as the contractor cannot be expected to make decisions on site that may affect the insulation co-ordination of the panels.

The metal-clad switchgear used by Eskom is designed to always accommodate the following arrangement of cables relating to the rating of the panel:

Table 2 – Cable size for metal-clad switchgear rating

Rating (Amps)	**Cable size**
800	2 × 185 mm^2 3-core
1250	2 × 630 mm^2 1-core / phase
2500	4 × 630 mm^2 1-core / phase

For each cable terminated into the panel a separate flag is provided for each lug to be connected (i.e. no back to back lug connections are accepted). This is to ensure that the live bare metal can be properly shrouded to meet the minimum clearances required by NRS 012. This philosophy is applied irrespective of whether the switchgear is designed for live bare metal or shrouded clearances for the following reasons:

- the cable jointer always applies the same type of termination; and
- to reduce the risk of the lug, bolt and nut connection compromising the required clearances. An example of where this has occurred on site is shown in photo 8.

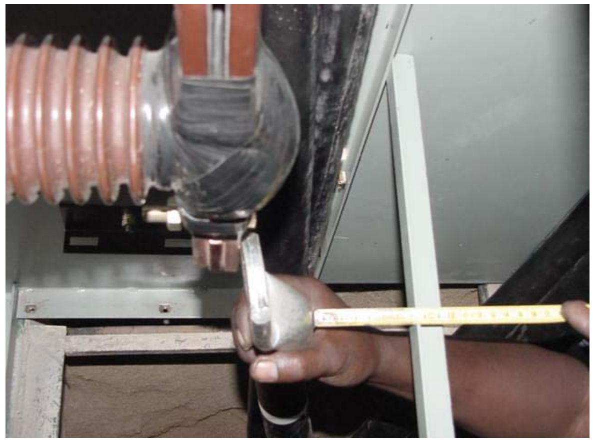

Photo 8 – Inadequate clearance due to installation of lug on 2500 A panel

Photo 9 illustrates a panel where the philosophy of a separate tag and support is provided for each incoming cable. Each panel is also supplied with a vermin proofing plate that is pre-drilled and fitted with tapered rubber grommets that are cut on site to suit the cable diameter.

Photo 9 – Provision for incoming cables on 2500 A panels

An 800 A panel is often connected by means of a length of cable to an overhead line. In the event that additional surge arresters are required to be installed in the panel, it is necessary to ensure that this can be done in a way that the clearances required by NRS 012 are met. The compactness of certain designs of switchgear prohibits the use of conventional outdoor surge arresters and necessitates the use of fully shrouded indoor arresters. This is illustrated in photo 10 and 11.

3.2 CABLE

The debate regarding the benefits of XLPE-insulated cable versus impregnated paper insulated cable (PILC) continues and will not be discussed in this paper. The Eskom standard caters for both types of cable and the application of either is based upon:

- installations in “Greenfield” areas versus extensions to existing networks; and
- the type of equipment, system voltage and related accessories that are to be used i.e. the fact that SSC’s cannot be used with PILC cables is often overlooked by the users.

Photo 10 – Outdoor surge arresters fitted with insufficient clearances

Photo 11 – Indoor surge arresters fitted with sufficient clearances

The London Metals Exchange price of copper and aluminium dictates the type of conductor that is most cost effective at any particular time. Eskom however has standardised on copper conductors for the following reasons:

- to minimise the stockholding requirements to cater for both types of cable (i.e. lugs, ferrules, cable etc.);
- the core and outer diameters of a copper conductor cable are smaller for equivalent ampacity than an aluminium conductor cable facilitating easier working when jointing and terminating;
- conductor jointing using compression methods are simple for copper conductors whereas there are numerous differing opinions regarding the crimping requirements for aluminium cables; and
- to avoid the bimetallic corrosion problems associated with termination and jointing of aluminium cables (i.e. brass or copper terminals on equipment).

The problems with water treeing in XLPE-insulated cables are well documented. Eskom has adopted the recommendation made by SABS 1339 [8] to use a polyethylene outer sheath on all MV XLPE cable as it is more robust and impervious to water than PVC. A drawback with PE is its flammability and therefore in applications where the cable is exposed above ground level (e.g. when terminating to an overhead line), special precautions needs to be taken. In these cases a protective steel pipe is used.

The lead sheath or armour of the cable is used as the earth continuity conductor (ECC) of the cable feeder. In order for the cable to perform this function, the rating of the earth circuit must be greater than 2 kA for 3 seconds. Using the lead sheath or armouring as the ECC implies that a separate counterpoise earth is not required to be installed with the cable.

3.3 CABLE ACCESSORIES

Prior to 1998 the supply of cable accessories (i.e. cable joints and terminations) to Eskom was not regulated. Although some Eskom regions partnered with suppliers that provided type tested products, the lack of control allowed opportunist suppliers to supply inadequate and untested accessories. In 1998 the Eskom and NRS 053 [9] specifications for MV cable accessories were published. In both cases the type test requirements were based upon IEC 60055-1 [10], IEC 60502-4 [11] and equivalent CENELEC specifications. Since 1999 Eskom has committed to purchasing only cable accessories that are type tested accordingly. This is controlled by a published list of approved suppliers and products that is reviewed on a two yearly basis.

The Eskom specification for MV cable accessories has the following unique requirements:

- user as opposed to supplier defined standard accessory ranges i.e. to simplify stockholding etc.;
- the primary earthing connections (i.e. to the lead sheath or armour wires) in accessories are required to withstand the maximum prospective earth fault level and duration (i.e. 2 kA for 3 seconds). The connections are made using type tested mechanical arrangements;
- resin or mastic filled XLPE cable joints. The philosophy is to provide a water block preventing water migration through the joint. This is done in conjunction with the use of solid centre ferrules;
- top down measurement principle for three-core cable terminations i.e. the top of the stress control tube is positioned as close as possible to the bottom end of the lug barrel. This is illustrated in figure 2. The philosophy is to maximise the screened section of the termination tails and hence increase the clearance between the unscreened cores. The majority of termination failures found in Eskom have been attributed to electrical discharge between unscreened termination tails that have had inadequate clearances between cores.
- Unscreened separable connectors/shrouds (USC's) that are suitable for use with the standard interface (i.e. 630 A Type C M16 x 2) bushing. The USC's are used exclusively at 11 kV and are used in conjunction with an indoor termination. The USC – bushing interface is an interference fit that provides a tight seal encapsulating the live bushing terminal. The purpose of this is to eliminate the creepage requirement that would typically be required if an exposed live terminal connection was made;
- Screened separable connectors (SSC's) that are suitable for use with the standard interface (i.e. 630 A Type C M16 x 2) bushings. The SSC's are used exclusively at 22 kV and can only be used with XLPE cable. Again the SSC – bushing interface is an interference fit that provides a tight seal encapsulating the live bushing terminal however with a screened outer surface. The purpose of this is to eliminate both the creepage and clearance requirement that would typically be required if an exposed live terminal connection was made.

3.4 COMPACT SWITCHGEAR (E.G. RING MAIN UNITS)

Extensible and non-extensible compact switchgear is required for two applications in the Eskom Distribution context i.e.:

- the provision of sub-switching stations; and
- provision of ring main units (RMU's) on the MV side of miniature substations (mini-subs).

At 22 kV there is no option but to use SF6 gas-insulated switchgear for the above applications as no alternative exists. However, at 11 kV the option exists of using either oil or SF6 gas-insulated switchgear. The Eskom decision to use either is based upon a total cost of ownership study that was done using the Electric Power Research Institute (EPRI) Life-Cycle Cost Management System (LCCMS) software. The alternatives evaluated were:

- oil-insulated switchgear that undergoes routine maintenance every three years. The assumed maintenance frequency and average cost of maintenance is based upon Eskom experience with the installed base of oil-insulated compact switchgear;
- SF6 gas-insulated switchgear that is un-maintained.

The two alternatives were analysed for the acquisition, use and disposal phases of their life-cycle. The results are shown in figure 3.

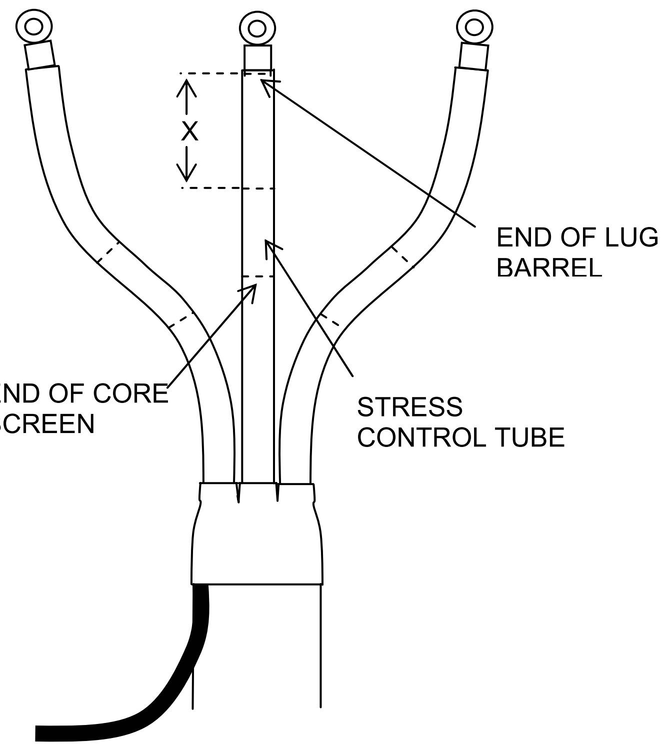

Figure 2 – Illustration of "top down" measurement principle

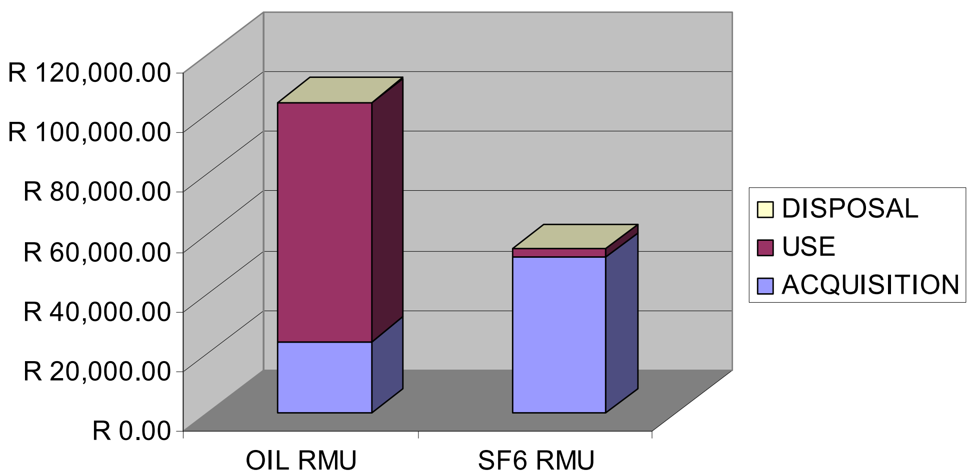

Figure 3 – Total cost of ownership of oil versus SF6 gas-insulated switchgear

The two most significant cost elements that make up the "Use" cost factor for oil-insulated switchgear are:

- the 3 yearly maintenance cost; and
- cost of unserved energy that occurs while doing maintenance.

The cost of unserved energy is based on R/kWh figures provided annually by the Eskom Finance Group [12] for residential, agricultural, commercial and industrial type customers. A sensitivity analysis performed on the cost of unserved energy cost element indicates that the use of oil-insulated switchgear is only cost effective in areas supplying residential type customers. In areas supplying agricultural, commercial and industrial type customers SF6 gas-insulated switchgear is most cost-effective.

The compactness of modern switchgear has resulted in cable box dimensions that barely provide adequate space to terminate the MV cable. In order to assist the cable jointer the switchgear specification requires direct and full access to the bushings for cable termination. This is best illustrated by photo 12 showing how all metalwork and plinth in front of the cable boxes is removed allowing full access to the cable boxes.

Photo 12 – Front cable access to compact switchgear

Photo 13 – Type A MV compartment

3.5 MINIATURE SUBSTATIONS (MINI-SUBS)

In order to gain a competitive advantage the manufacturers of mini-subs have tried to design the footprint dimensions of their mini-subs below those specified as a maximum by NRS 004 [13]. This practice has lead to mini-subs with varying footprints. In practice, a mini-sub that is significantly shorter than the plinth on site presents as much of an installation problem as one that is too long. In order to overcome this interfacing problem, Eskom has specified that the mini-sub footprint dimensions shall always be equal to the NRS 004 maximum dimensions.

In terms of the Eskom standard there are two types of mini-subs, i.e.:

- Type A, which is equipped with a dead-break isolating arrangement in the MV compartment. This arrangement allows for two incoming cables that can be connected together and either of which can be connected to the transformer; and
- Type B, which is equipped with compact switchgear in the MV compartment providing a RMU.

The Type A mini-sub is used when a mini-sub is to be supplied from a radial feed (e.g. a cable T-off from an overhead line) or when the cost of a RMU is hard to justify. However the additional cost of unserved energy incurred during the operating of the dead-break isolating arrangement in the MV compartment of the Type A mini-sub makes it cost effective only in pure residential areas. With the advent of many customers operating businesses from home, pure residential areas are rare.

3.6 GROUND MOUNTED TRANSFORMERS AND CT-VT UNITS

Ground mounted transformers (i.e. with MV and LV cable boxes) and current and voltage transformer combination (CT-VT) units are locally manufactured. The Eskom specification for these transformers and CT-VT units take advantage of local manufacturing by requiring the MV cable box dimensions for 11 kV units to comply with NRS 012 clearances for USC type terminations. The 11 kV cable box dimensions are therefore significantly larger than those supplied with imported compact SF6 gas-insulated switchgear. This is shown in photo 14. At 22 kV the dimensions of the MV cable boxes are required to provide adequate physical clearances to terminate the cable using SSC's i.e. no electrical clearances required.

4. INSTALLATIONS

4.1 PLINTHS

Although the use of pre-cast plinths is not new, the Eskom standard plinths used with compact switchgear and mini-subs are unique in terms of the removable sections adjacent to the MV cable connection areas. As mentioned previously the sections are removed on site to provide the cable jointer with full access to the cable boxes.

Photo 14 – CT-VT unit MV cable box

Photo 15 – Pre-cast plinth for mini-sub

5. SAFETY MEASURES

5.1 PROTECTION FROM DANGERS RESULTING FROM AN ARC FAULT

Since 1998, the trend in the specification of metal-clad switchgear has been to focus on the internal arc testing of the panels to ensure the safety of the operator during switching. Eskom has not only enforced this requirement for metal-clad switchgear but also carried the philosophy through to the compact switchgear used for sub-switching stations typically found downstream of metal-clad switchgear. The implementation of this philosophy at sub-switching station level is a good example of the evolution of a user requirement into a type tested product. This can be described as follows:

- in 1999 it was specified that all air and/or gas-filled enclosures of the compact switchgear (e.g. ring main unit) shall be internally arc tested and shall be fitted with suitable explosion vents to ensure overpressure release in a controlled manner to the atmosphere during an internal arc fault;
- although the above requirement was met by the suppliers of compact SF6 gas-insulated switchgear, there was little cognisance paid to the fact that the switchgear was being installed in enclosures that did not form part of the original type test. Furthermore no effort was made to design the enclosure in a way that complimented the internal arc proof design of the switchgear;
- in 2000 Eskom specified that the cable boxes should also be internally arc tested and that the design and construction of the enclosure (i.e. mini-sub housing or kiosk) shall complement the internal arc-test requirements of the compact switchgear i.e. the enclosure

shall be designed for the safe venting (i.e. away from the operator) of gases released during an internal arc fault. Enclosures housing compact switchgear were manufactured for Eskom that were designed with an arc proofing philosophy in mind. This is illustrated in photo 16; and

- presently at least two major manufacturers of compact switchgear have type tested their switchgear and kiosk combinations to prove that they meet the internal arc requirements of both Eskom and SANS specifications.

Photo 16 – Arc proofing of enclosures

5.2 PROTECTION OF PERSONS WORKING ON ELECTRICAL EQUIPMENT

Eskom has adopted a philosophy on all ground mounted equipment that ensures that all live parts within an enclosure are barricaded to prevent inadvertent contact being made by an operator requiring access. This includes the barricading of any unscreened MV insulation.

Photo 17 – Barricading of live equipment

CONCLUSIONS

In the process of developing an MV Standard for Cable Systems, Eskom has produced a number of unique solutions to the problems experienced in the past. However, there still remain areas that require further research and effort. These may be summarised as follows:

- In order to determine the long term performance of outdoor terminations and USC products used in Eskom, it is intended that natural ageing tests will be carried out at Eskom's insulator products test site at Koeberg in the Western Cape.
- The design of cable joints for PILC cable currently being sold in the market place are based upon a mastic or resin filled version of the traditional compound filled joint i.e. a collectively and not individually screened joint. Firstly, the joint design is not consistent with the cable design i.e. most users are using individually screened PILC cables. Secondly, as joints for PILC cables are not required to undergo partial discharge type testing, the mastic or resin used in conjunction with polymeric shrink tubes is not tested to ensure that it is discharge free.
- The problems experienced by Eskom in trying to train internal cable jointers on MV cable accessories that have instructions that vary significantly from one supplier to another have led to the development of a set of standard accessory installation instructions. Ultimately Eskom would like to see a formal accreditation system in place for cable jointing.
- Eskom is presently evaluating alternative MV XLPE cable designs with the intention of improving the cable's ability to prevent water ingress and subsequent water tree development.

REFERENCES

[1] SCSASABL6, *General information and requirements for medium-voltage cable systems.*

[2] SABS 0200:1985, *Neutral earthing in medium voltage industrial power systems.*

[3] EN 50181:1999, *Plug-in type bushings above 1 kV up to 36 kV and from 250 A to 1,25 kA for equipment other than liquid filled transformers.*

[4] NRS 012, *Cable terminations and live conductors within air-insulated enclosures (insulation co-ordination) for rated a.c. voltages of 7,2 kV and up to and including 36 kV.*

[5] SABS 1019:1985, *Standard voltages, currents and insulation levels for electricity supply.*

[6] IEC 60071:1993, *Insulation co-ordination.*

[7] CENELEC HD 428.2.2 S1:1997, *Three-phase oil-immersed distribution transformers 50 Hz, from 50 kVA to 2500 kVA with highest voltage not exceeding 36 kV – Part 2: Distribution transformers with cable boxes on the high and/or low voltage sides – Section 2: Cable boxes type 1 for use on distribution transformers meeting the requirements of HD 428.2.1 S1.*

[8] SABS 1339:2000, *Electric cables – Cross-linked polyethylene (XLPE)-insulated cables for voltages from 3,8/6,6 kV up to 19/33 kV.*

[9] NRS 053:2000, *Accessories for medium voltage power cables (3,8/6,6 kV to 19/33 kV).*

[10] IEC 60055-1:1997, *Paper-insulated metal-sheathed cables for rated voltages up to 18/30 kV (with copper or aluminium conductors and excluding gas pressure and oil filled cables) – Part 1: Tests on cables and their accessories.*

[11] IEC 60502-4:1997, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) – Part 4: Test requirements on accessories for cables with rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV).*

[12] 2002 Economic Evaluation Parameters, Eskom Finance Group.

[13] NRS 004-1: 1991, *Mini-substations – Part 1: Mini subs for rated a.c. voltages up to 12 kV.*