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CAPACITOR BANKS**

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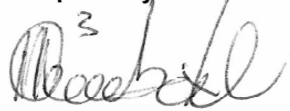
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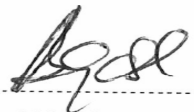


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1. Introduction

The purpose of this document is to outline safety precautions to be followed before any work is carried out on capacitor banks.

2. Supporting clauses

2.1 Scope

2.1.1 Purpose

This document sets out the rules to protect people working on capacitor bank installations. It covers all the banks in Transmission network.

2.1.2 Applicability

This document shall apply in Transmission and Distribution throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

- [1] ISO 9001 Quality Management Systems.
- [2] TGL41-379 Shunt Capacitor Neutral Earthing
- [3] Occupational Health and Safety Act, Act 85 of 1993
- [4] E32-846 Operating Regulations For High Voltage Systems
- [5] EPC_32-166 Code of Practice for the Application of Earthing Gear on High Voltage Systems
- [6] IEC 60143 Series Capacitors for Power Systems
- [7] IEC 60871 Shunt Capacitors for A.C Power System having rated voltage above 1000V
- [8] General Machinery Regulations, GN R1521 of 5 August 1988
- [9] 240-86739036 Standard For The Management Of PCB Capacitors

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

Definition	Description
Authorised Person	As per Eskom document E32-846 Authorised person is described as a person, whether an employee or another person, who has been authorised as per ORHVS.
Breakdown Maintenance	Breakdown maintenance is that maintenance which is done after a failure has happened. A failure would be a fuse rupturing, or a unit blowing up or leaking, any break of a primary connection or any protection operation except an Over voltage trip. (Over voltage trip is an external network related condition to the plant).

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Definition	Description
Capacitor Bank	Capacitor bank is a series and parallel combination of capacitor units constructed for the purpose of improving power factor or improving voltage stability or increasing power transfer.
Capacitor Unit	Capacitor unit is the name given to an assembly of capacitor elements contained in a protective case, with one or two terminals. The previous name for this device was capacitor can.
Control Earth	According to EPC_32-166 control earth is either an earth switch or a portable earth that is applied and removed on instruction from control
Discharge Earth	Section 3.6.1 of EPC_32-166 defines discharge earth as a working earth designed and constructed to protect against capacitive voltage and current that shall always be used in addition to control earths.
Earthing	According E32-846 earthing means the electrical connection between an apparatus and the general mass of earth in such a way that it will ensure a safe discharge of electrical energy at all times.
Maintenance	Maintenance or "normal maintenance" is done on plant to restore it to an acceptable state and only addresses normal wear and tear. No fault has occurred on the plant.
Safety Earthing	This type of earthing is done by means of control earths which will provide protection against accidental energisation.
Vermin Proof	Is the protection of equipments (capacitor bank) against small animals from making contact with live electrical points.
GMR 2.1	A person designated in writing in terms of General Machinery Regulation section 2.1 of OHSA by the employer (Eskom), or a user of machinery.
16.2	A delegated employer in terms of section 16.2 of the OHSA on behalf of Eskom, that is responsible for health and safety during construction work.

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
GMR	General Machinery Regulation
HV	High Voltage
MVar	Mega Volt-Ampere Reactive
OHSA	Occupational Health and Safety Act
ORHVS	Operating Regulations for High Voltage Systems
OU	Operating Unit – Distribution
V	Voltage

2.5 Roles and responsibilities

2.5.1 Implementation of the Standard

Implementation of this standard is the responsibility of the relevant GMR 16.2 appointee in each Grid.

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2.5.2 Bank Specific Earthing Procedures

The GMR2.1 appointee for the Grid/OU and the 16.2 appointee for the Grid/OU are responsible for the drawing up and the regular revision of Safety Earthing Procedures for the capacitor banks in their Grids/OU. Each capacitor bank will have its own specific procedure; however similar banks may have the same procedure.

The Capacitor Work Group will assist the Grids/OUTs and will always “see and accept” the completed earthing procedure. The earthing procedure per bank shall state what type of fusing technology is utilized and reference to be made to the type of discharge resistors the specific bank is equipped with. The time required for the discharge resistors (internal or external) to discharge the bank shall be mentioned in the procedure.

NOTE: The continuity of the neutral earthing cable in single point earthed banks is of critical importance for the safety of people working on the bank. The earthing procedure shall mention the need to maintain the continuity of this connection in place at all times. It may be necessary to enclose the connection to earth in a lockable enclosure to ensure that the connection to earth is not inadvertently broken.

2.5.3 Authorisation of operators

Each Grid/OU HV Plant Manager shall ensure that they do not authorise a person to perform the earthing of capacitor banks unless he/she has successfully completed the necessary training and has been tested to prove his/her competence.

Authorisation to do capacitor discharge earthing shall be valid for a maximum period of 3 years.

It is mandatory that the authorisation to do capacitor earthing shall be specifically listed on the operators' authorisation letter.

2.6 Process for monitoring

Audits requested periodically from Performance and Audit section.

2.7 Related/supporting documents

TPL 41- 142 is superseded by this document.

3. Document content

3.1 General Guideline

3.1.1 Discharge Devices

As a minimum requirement IEC 60871 states that each capacitor unit shall be provided with means for discharging to 75V or less from initial peak voltage of $\sqrt{2}$ times rated voltage U_n . The maximum discharge time is 10 minutes.

Capacitor units in the Distribution and Transmission system use resistors as a means to discharge. These capacitor units are categorized into three groups. There are those with internal discharge resistors, those with external discharge resistor and those without discharge resistors.

3.1.2 Minimum Earthing Requirements

E32-846 states that when a capacitor bank has been isolated from all points of supply and tested in accordance with the Operating Regulations For High Voltage Systems, it shall be earthed at all points of supply. Adequate earths shall be applied in accordance with equipment specific earthing procedure to ensure that the possible trapped charges will be discharged for the duration of the work.

3.1.3 Safety Precautions

When any work is to be performed on a capacitor unit or when any unit fails or when the fuse of an externally fused capacitor unit ruptures, the capacitive elements may be left holding a charge. The internal discharge resistor will dissipate this charge within 5 to 10 minutes to 75V or less, if the resistor is in place. The experience in on site to date is that the internal resistors are reliable. However, no specific tests are done, either while the unit is healthy or after each failure, to give confidence that the resistor will always be in place. For safety's sake, it must be assumed that the resistors are not in place and that a charge may be resident in the capacitor unit.

Before contact is made with any unit, a short (a piece of conductor) should be placed between the bushing terminals and unit tank/earth using an insulated link stick.

If the unit is known to be faulty or if the operator suspects that the unit is faulty, a permanent short shall be installed across the terminals after the unit has been shorted using the link stick. Only after this has been done, may the unit be removed. The unit shall not be opened by staff under any circumstances.

NOTE: At all times care must be taken to ensure that no person makes contact with any capacitor terminal until the terminals are discharged. The unit shall be clearly and indelibly marked as being faulty and must carry a permanent label warning that the unit may be charged and must thus be regarded as dangerous at all times. The terminals must be shorted at all times and connected to the tank if not in service.

3.1.4 Fusing Technologies

Three types of fusing technologies are used in the Distribution and Transmission capacitor units and those are, external fusing, internal fusing and fuseless technology. The approach to earthing may vary according to the technology used per bank.

3.1.5 Earthing Methods

There are three methods of earthing the capacitor bank. The earthing method depends on the type of work to be executed. The methods are Simple Earthing, Selective Earthing and Full/Total Earthing.

NOTE: Enter the "Live Chamber" only once "Safety Earthing" has been applied and a permit is issued. Ensure that capacitor units and racks are not touched before safety earthing is done. When doing any type of earthing refer to bank specific earthing procedure.

NOTE: Every bank shall have a specific earthing procedure unique to it and it must be kept at the substation. This procedure must be followed before commencing any work on capacitor banks.

3.1.5.1 Simple Earthing Method on Capacitor banks

This earthing method is recommended for visual inspection or scheduled maintenance when no fault occurred. Minimum earthing that can be applied is as follows:

- Earth the HV incoming side as per Eskom ORHVS
- Earth steel structure of all racks reachable from ground level
- Earth the star point
- Earth all the racks (all earthing points on the selected racks)

3.1.5.2 Selective Earthing Method on Capacitor banks

This earthing method is recommended for breakdown maintenance only on a faulted phase. If a faulted phase can be located either visually or through protection relay, selective earthing can be applied. Unfaulted phases should be barricaded and full earthing as per bank specific earthing procedure should be done on the faulted phase.

3.1.5.3 Full or Total Earthing Method

This earthing method is recommended for breakdown maintenance. Earthing will be done on all phases according to bank specific earthing procedure.

3.2 Safety Earthing Policies

Sections 3.3, 3.4 and 3.5 of this standard define the safety earthing standard for internally fused, externally fused and fuseless capacitors that have internal discharge resistors.

Section 3.6 defines the safety earthing standard for the capacitors that do not have internal discharge resistors. These banks have externally mounted and connected discharge resistors.

Section 3.7 defines the safety earthing standard for the capacitors that do not have discharge resistors.

3.3 Safety Earthing Standard for Banks with Internally Fused Units

3.3.1 Risk Statement

Internally fused capacitor units are connected in parallel groups and so the possibility of all internal discharge resistors in a parallel connected group being faulty is acceptably low.

3.3.2 Earthing Standard

3.3.2.1 Maintenance outage or Inspection

If the bank is taken out of service for maintenance or inspection activities, then the bay shall be earthed according to the ORHVS – earth switches (if applicable) and parallel earths. If the bank has a platform, it shall be earthed by means of a discharge earth. The neutral or star point shall be earthed via a discharge earth in the case of shunt and filter capacitor banks. All racks that contain capacitor units shall be earthed.

3.3.2.2 Break down maintenance

If the bank is taken out of service for breakdown maintenance, then the following earthing and shorting shall be carried out:

- The bay shall be earthed according to the ORHVS, and as per section 3.3.2.1 of this document.
- The platform and/or steel racks shall be earthed.
- All of the units in close proximity to the damaged units shall be shorted out and earthed to their cases.
- Units shall not be moved from the rack unless the terminals are permanently shorted together and, if possible, connected to the case.

3.4 Safety Earthing Standard for Banks with Externally Fused Units

3.4.1 Risk Statement

Externally fused capacitor units are connected in parallel groups and they have a much higher risk of being left charged than the internally fused or fuseless units. This could be the case when the fuse operates and the unit is disconnected from the parallel path to the rest of the units in the same rack. The fuse must be selected to withstand parallel discharge of adjacent capacitor units.

3.4.2 Earthing Standard

3.4.2.1 Maintenance outage or Inspection

If the bank is taken out of service for maintenance activities, then the bay shall be earthed according to the ORHVS – earth switches (if applicable) and parallel earths applied. If the bank has a platform, it shall be earthed by means of a discharge earth. The neutral or star point shall be earthed via a discharge earth in the case of shunt or filter capacitor banks. All racks that contain capacitor units shall be earthed.

3.4.2.2 Breakdown maintenance

If the bank is taken out of service because of a breakdown (primary damage or fuse rupturing etc) has occurred, then the following earthing and shorting shall be carried out:

- The bay shall be earthed according to the ORHVS, and
- The platform and/or the steel racks shall be earthed
- All of the units in close proximity to the damaged units shall be shorted out and earthed to their cases.
- Units shall not be moved from the rack unless the terminals are permanently shorted together and connected to the case.

3.5 Safety earthing standard for banks with fuseless units

3.5.1 Risk statement

Capacitor units are connected in series strings between phase and neutral. Fuseless units have similar risk of being left charged as the internally fused units but much lower than externally fused units. The reason being that the discharge energy is small since there are no units connected directly in parallel.

3.5.2 Earthing Standard

3.5.2.1 Maintenance outage or Inspection

If the bank is taken out of service for maintenance activities, then the bay shall be earthed according to the ORHVS – earth switches (if applicable) and parallel earths applied. If the bank has a platform, it shall be earthed by means of a discharge earth. The neutral or star point shall be earthed via a discharge earth. All racks that contain capacitor units shall be earthed.

3.5.2.2 Breakdown maintenance

If the bank is taken out of service because a breakdown has occurred, then the following earthing and shorting shall be carried out:

- The bay shall be earthed according to the ORHVS, and
- The platform and/or the steel racks shall be earthed
- All units in close proximity (units in the same rack, upper and lower rack) to the damaged units shall be shorted out and earthed to their cases.
- Units shall not be moved from the rack unless the terminals are permanently shorted together and connected to the case.

3.6 Safety Earthing Standard for Banks with External Resistors

3.6.1 Risk Statement

This type of capacitor units have internal fuses and external discharge resistors and are connected in parallel groups of 8 or 9 units. One externally mounted discharge resistor is connected to each parallel group of units. The possibility of losing this external discharge resistor is not high but Infrared scanning experience has shown that the connection between the parallel group and the resistor is a weak spot in the rack.

3.6.2 Earthing Standard

3.6.2.1 Maintenance outage or Inspection

If the bank is taken out of service for maintenance activities, then the bay shall be earthed according to the ORHVS – earth switches and parallel earths and platform earths applied. All racks that contain capacitor units shall be earthed.

3.6.2.2 Breakdown maintenance

If the bank is taken out of service because a breakdown or a protection operation has occurred, then the following earthing and shorting shall be carried out.

- The bay shall be earthed according to the ORHVS,
- The platform and/or the steel racks shall be earthed via a discharge earth
- The operator may erect barricades on the platform to prevent access to the unaffected portions of the platform. All of the parallel groups in the unbarricaded section(s) shall be shorted out by means of an insulated lead with “crocodile clips” between terminals and cases. Units shall not be moved from the rack unless the terminals are permanently shorted to the case.

NOTE: That if the bank bypasses (*when a series capacitor bank breaker closes under fault condition to bypass the bank*) and a unit is not obviously damaged, then the bank has to be measured, section by section, to find the affected units. This means that all of the units on the platform will have to be earthed in turn.

3.7 Safety earthing standard for banks without discharge resistors

3.7.1 Risk statement

The capacitor units on these capacitor banks have no discharge resistors and are connected in parallel groups. These banks are dangerous and the units must be regarded as being charged until comprehensive earthing is done.

3.7.2 Earthing Standard

3.7.2.1 Maintenance outage, Inspection or Breakdown maintenance

If the bank is taken out of service for any maintenance or inspection activities the following earthing method shall be carried out:

- The bay shall be earthed according to the ORHVS – earth switches (if applicable and parallel earths.
- The platform and or steel racks shall be earthed via a discharge earth
- All the parallel groups shall be shorted out between terminals and cases by means of insulated link stick
- Units shall not be moved from the rack unless the terminals are permanently shorted together and connected to the case.

NOTE: All racks shall be earthed

3.8 Important operating constraints

In stations where more than 1 shunt capacitor is installed, it is common practice to insulate the star point of each bank to about 22kV above earth potential and then to connect the star points of the banks with insulated HV cable to a single earth point on the earth mat.

It is VITALLY important that the connections between the star points and between this common connection rail and the earth mat are never disconnected. Refer to standard TGL41-379 SHUNT CAPACITOR NEUTRAL EARTHING for more details on the design aspects of this issue.

Training courses must stress the risk of disconnecting any of these connections.

3.9 Environmental Aspects

3.9.1 Handling procedures for capacitor units

3.9.1.1 Destruction of faulty (out of specified C value tolerance, leaking or broken bushings) PCB units

Faulty PCB units shall be disposed of in accordance with the relevant standard for the management of PCB capacitors (240-86739036). In short, the units shall be placed into the yellow containers that are on site. The contents of these containers shall be disposed through burning by accredited vendors. The Chairman of the Capacitor Working Group will have a list of suitable vendors who are competent to do this destruction.

3.9.1.2 Destruction of faulty non-PCB units

The units shall be sent for destruction to adequately skilled and equipped vendors. The Chairman of the Capacitor Working Group will have a list of suitable vendors who are competent to do this destruction. The vendor must be advised in writing that the unit may be charged and must be regarded as dangerous at all times. The vendor shall acknowledge receipt of the warning in writing.

3.10 Mandatory Practices

3.10.1 Earthing practice

Shunt, filter or series capacitors must be considered fully charged and dangerous, although disconnected from the system. Therefore safety earthing procedure must be followed before any work commences on capacitor banks.

For this reason, the capacitor units in the affected part of the bank shall be solidly earthed and short circuited by means of the control or discharge earths, and kept earthed for the full period while work is being carried out.

Earths shall be applied from the lowest point upwards and removed in reverse order.

3.10.2 Entering / Accessing Capacitor Live Chambers

Note that ground access to a capacitor live chamber for maintenance or inspection purposes is permitted ONLY when the bank has been de-energised, the control earths have been applied and the platform(s) has(have) been earthed by means of discharge earths.

3.10.3 Removal of earths while testing units

When units are to be tested, they shall be shorted and earthed in accordance with this standard. After this has been done, the discharge earths and shorts may be removed for testing. When the testing is complete, these shorts and earths shall be replaced. Note that if the control earths have to be removed for testing, this shall be done strictly in accordance with the Regulation 5.09 of EPC_32-846.

3.10.4 Fixed Point Earth Studs

Earth studs are to be permanently fixed on each platform or support steelwork of all capacitor banks where the earths should be applied. The earth studs are to be directly connected to the earth mat by means of the control earths whenever the bank is to be earthed for access purposes. The earth studs shall be placed in such a manner that persons applying the earths does not need to approach too close to the units.

3.10.5 Vermin proofing

If vermin proofing (bird caps) has been installed, the operator shall remove it by means of a link stick. The vermin proofing may also be removed by hand, provided that suitably rated insulated gloves are worn. The voltage withstand rating of the gloves shall be at least twice the voltage rating of the capacitor units.

3.11 Revision Control

The Capacitor Work Group Chairman is responsible for updating this document.

4. Authorization

This document has been seen and accepted by:

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5. Revisions

Date	Rev.	Compiler	Remarks
March 2015	1	MM Moabelo	The previous revision had expired The document template / format and ref. number changed to 240-85660696 Document amended to include DX and this copy supersedes document referenced TPL 41- 142
March 2011	1	K Maithufi	New document

6. Development team

The following people were involved in the development of this document:

- Mashilo Moabelo
- Neels van Staden

7. Acknowledgements

Not applicable.