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## FIGURES

# 1. INTRODUCTION

This document is to ensure a uniform approach to DC Earth Fault detection.

# 2. SUPPORTING CLAUSES

## 2.1 SCOPE

### 2.1.1 Purpose

See introduction.

### 2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions on:

- Newly installed or upgraded DC Earth Fault detection schemes.
- This standard is applicable to 220/110VDC supplies making use of high resistance earthing.

## 2.2 NORMATIVE/INFORMATIVE REFERENCES

### 2.2.1 Normative

[1] ESKASAA04: Standard for electronic protection and fault monitoring equipment for power systems.

[2] 240-56227426: MV and LV Philosophy for Eskom Power Stations.

[3] 240-56356510: Definitions of Terms Applicable to DC Emergency Supplies Standard

### 2.2.2 Informative

None

## 2.3 DEFINITIONS

None

### 2.3.1 Disclosure Classification

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

## 2.4 ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| AC | Alternating Current |
| DC | Direct Current |
| LED | Light Emiting Diode |
| mA | Milli-ampere |

## 2.5 ROLES AND RESPONSIBILITIES

None

## 2.5 PROCESS FOR MONITORING

None

## 2.6 RELATED/SUPPORTING DOCUMENTS

None

# 3. OPERATION AND APPLICATION

## 3.1 EARTH FAULT DETECTION METHODS AND EARTHING ARRANGEMENTS

### 3.1.1 Earth Fault Detection using the EF100 Relay

The method used for DC earth fault detection, illustrated in **Figure 1**, consists of a voltage operated (EF100 or similar) relay placed between the artificially created centre point of the battery and earth. When an earth fault occurs, this relay, located at the battery charger, operates to indicate either positive or negative earth faults using LED indication and initiate a remote alarm. The relay sensitivity is continuously adjustable between 4 mA and 20 mA.

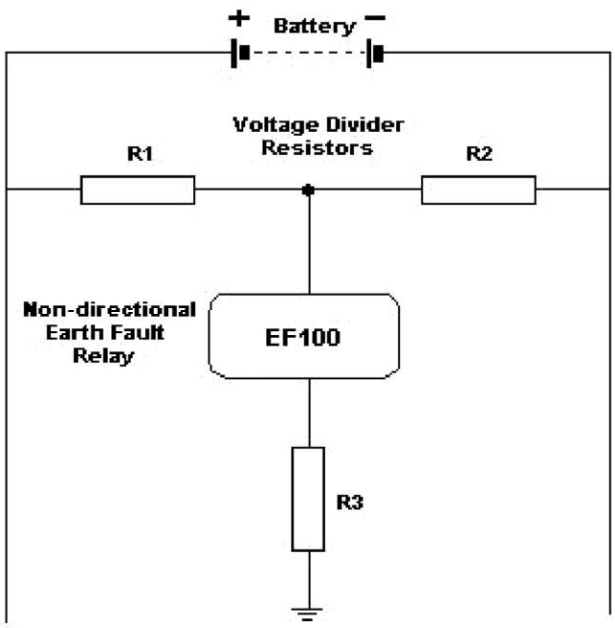


**Figure 1: Artificial Centre Point Resistance Earthing**

This system cannot indicate the exact location of the earth fault and only indicates if the earth fault is either positive or negative.

Portable fault locating instruments to determine the exact location of a DC earth faults can be used. This equipment operates on the principle of injecting a low frequency signal into the pole which has the earth fault while an inductive pick-up sensor is used to trace the signal to the point at which the earth fault has occurred. This method has the advantage that the DC supply need not be isolated while locating an earth fault. Unfortunately certain of these portable instruments have caused unit trips because they have not been applied correctly and others are somewhat erratic and unpredictable making it difficult to trace an earth fault under certain conditions.

In the event of a single earth fault on the load side of a fuse, the positive or negative fuse would not rupture. The low fault current would activate the relay and an alarm would be displayed. If a second earth fault on the opposite pole was to occur before the first is cleared, the positive and negative fuses would then rupture. The fault current between the artificial mid-point of the battery through earth and back into the circuit to the opposite pole of the battery through a link would be very small due to the high resistance circuit.

The conventional method of locating an earth fault is to isolate each circuit in turn until the alarm condition disappears, at which point the earth fault will be found. The disadvantage of this is that successive isolation of circuits is necessary which may not be convenient.

### 3.1.2 Earthing Arrangements

There are several established methods of earthing battery operated DC systems, the most common of which are:

a. Solid earthing of negative pole

b. Solid earthing of positive pole

c. Solid earthing of centre point

d. Resistance earthing of centre point (artificial centre point earthing)

e. Screened earthing

#### 3.1.2.1 Solid Earthing

For light current applications, tele-command, control metering and solid state electronic equipment a battery earthed solidly at the positive or negative pole is preferred. Even for tripping and shutdown circuits the solidly earthed supply would be acceptable in most cases because the light current equipment would normally be backed up by 110 V or 220 V control at the switchgear itself, which would be resistance earthed.

For 110/220 V DC power supply systems, resistance earthing is preferred to solid earthing. This safeguards the integrity of the supply and permits the system to continue operating with single earth faults.

#### 3.1.2.2 Resistance Earthing

Eskom has adopted the artificial centre point method of resistance earthing illustrated in **Figure 1**. This is the method most favoured for protection, switch tripping and machine shutdown applications in power stations because of its simplicity and low earth fault current. It also eliminates the need for a mid point tapping on the battery.

#### 3.1.2.3 Screened Earthing

On certain supplies, such as the 24 V control and instrumentation supplies, special-earthing arrangements are made. The screened cables are earthed in such a way that the chance of damage due to external voltage spikes is minimal.

Screened earthing usually consists of separately insulated earth bars, to which one end of the screens of screened cables are connected. These earth bars are connected through separately mounted earth link panels to the main station earth. These elaborate earthing systems are designed by the suppliers of the electronic equipment to ensure protection of their equipment and circuits against outside noise, interference and voltage spikes.

### 3.1.3 Disadvantages of the Existing Method of Earth Fault Detection

a. The location of continuous earth fault is difficult and time consuming.

b. The location of intermittent earth fault is even more difficult.

c. The difficulty is compounded if there is more than one earth fault at the same time.

d. More than one person is needed to locate a fault.

e. There is a possibility of tripping important equipment if a second earth fault occurs.

f. There is a risk of unit and multiple unit tripping.

## 3.2 THE EL DeC EARTH FAULT RELAY

### 3.2.1 General

A relay has been developed that can detect an earth fault in a particular circuit. The relay, called the EL DeC relay operates by detecting an imbalance between the positive and negative currents in a circuit. An imbalance indicates an earth fault on the load side of the relay.

The relay operates on the principle of injecting an a.c. signal into a winding of a toroidal magnetic core, called the Transcore through which the positive and negative wires pass. Any difference between the positive and negative currents will cause a deformation of the a.c. flux in the core. This is detected by a second winding on the core and relayed back to an electronic relay.

By placing these relays at strategic points on theDC system, the time taken to locate the fault can be considerably less than the time taken using conventional methods, such as a low frequency injection tester.

The relay has the additional advantage of recording details of intermittent faults, provided the alarm contacts are connected to a computer alarm system or an event recorder.

When relays are placed in series with one another no advantage is gained by grading the sensitivity of the relays. The relay is not polarity sensitive nor is it directional.

The sensitivity of the relays can be factory preset between 12 mA and 1000 mA. The EL DeC relays supplied to Eskom are preset to a sensitivity of 12 mA and it is recommended that the EF100 relays are set at 20 mA. The 12 mA relays must be recalibrated at site by the supplier after they have been installed, as the sensitivity may change due to vibration and mechanical shock during delivery. As stated on the relay manufacturer’s pamphlet, the relay and Transcore must be matched. Matching the serial number on the relay with the serial number on the Transcore identifies matching pairs of relays and Transcores.

A new, improved version of the EL DeC relay has been developed by the same manufacturer using two toroidal cores. The advantage of this relay is that it is insensitive to vibrations and does not have to be recalibrated at site. The cores have an internal diameter of 100 mm to accommodate large DC conductors. A version using 50 mm diameter cores, the same size as the Transcore, is currently under development.

### 3.2.2 The EL DeC Relay

The EL DeC relay uses the current inbalance created by an earth fault to detect the fault. This is illustrated in **Figure 2**. The relay detects faults only on the load side and this feature has the advantage of speeding up the location of earth faults by narrowing down the location of an earth fault to a particular zone or area of the plant. This saves time and reduces the risk of tripping important equipment if a second earth fault occurs.

Full details of the operation, testing, sensitivity and specification can be found in the manufacturer's information pamphlet.

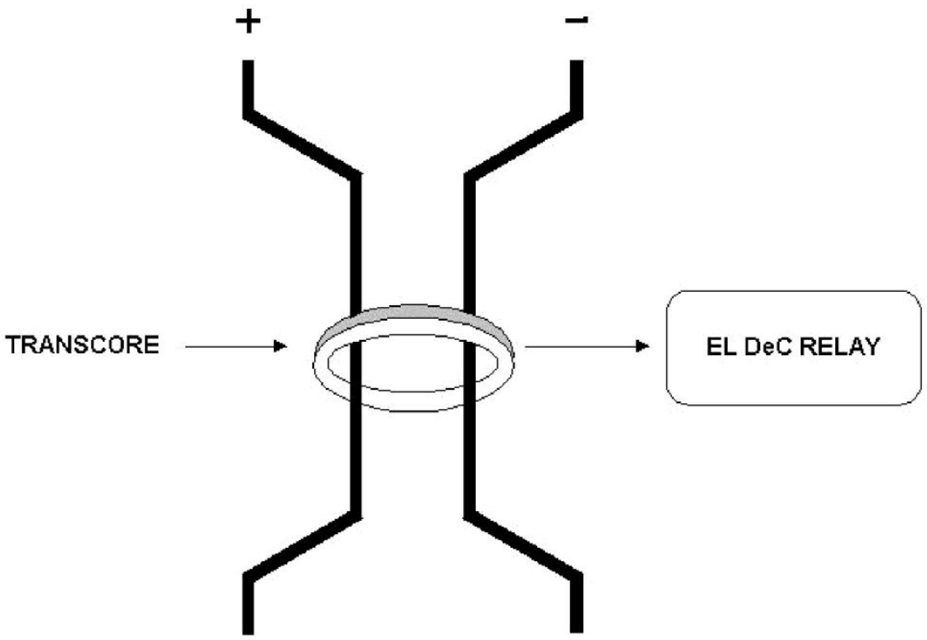


**Figure 2: Basic Principle Of Core Balance Relay**

### 3.2.3 Advantages of the EL DeC Relay

a. Reduced time in locating earth faults.

b. The location of simultaneous multiple earth faults is much easier.

c. The location of intermittent earth faults is much easier.

d. Only one person is required to locate earth faults.

e. It is cost effective in the long term.

## 3.3 PHYSICAL LOCATION OF DC EARTH FAULT RELAYS

### 3.3.1 General

In general the relays should be fitted to critical equipment, failure of which may cause the loss of a unit. **Figure 3** shows a typical layout of how the relays should be installed to gain maximum advantage of their features.

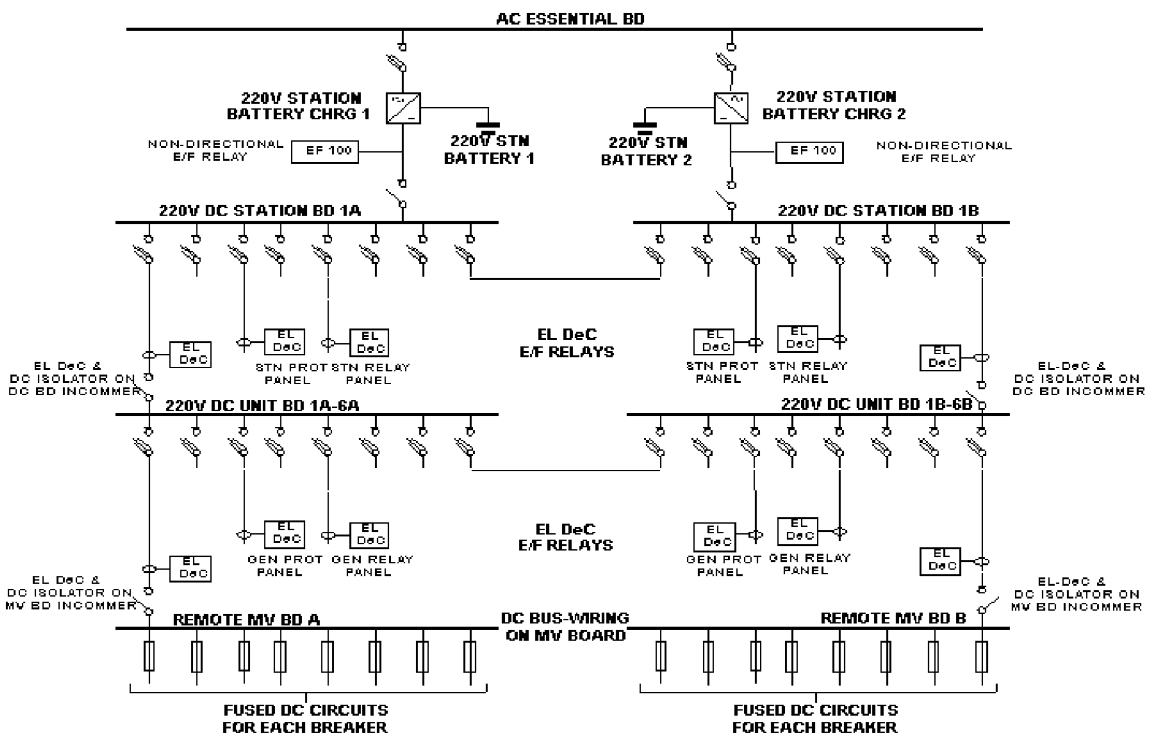


**Figure 3: Typical DC System**

As the DC earth fault relay has been designed to pin point earth faults down to a particular switchboard, it is essential that the relay is mounted as close to the switchboard where earth faults are most likely to occur. This is usually at the furthest point from the source of DC supply.

### 3.3.2 Relay Location

Earth fault detection should be installed on all major circuits as stipulated in 240-56227426: MV and LV Philosophy for Eskom Power Stations.

The standard EF100 earth fault relay is shown located at the source point while the EL DeC earth fault relays are located at the remote points. The EF100 is used for general earth fault detection of any part of the DC system, while the EL DeC detects an earth fault on a specific board.

In the case of MV switchboards two relays are recommended, as shown in **Figure 3**, one on each side of the bus section to monitor each DC incoming supply.

EL DeC DC earth fault relays should also be fitted to outgoing feeders on the DC boards that supply critical end point circuits such as Protection Relay panels. Only in special cases where it is not possible to physically fit the relays to end point circuits, should consideration be given to fitting the relays to outgoing feeders on the DC boards that supply the critical end point circuits.

For this relay to be most effective it should be placed as near to the DC control circuit load as possible and should be within sight and hearing of the person locating the earth fault.

To identify which circuit on the switchboard has an earth fault, each of the DC circuits will have to be sequentially isolated for brief periods, until the circuit with the earth fault is located. On isolating the circuit that has a DC earth fault, the LED on the EL DeC relay will switch off and a buzzer will sound to indicate the faulted circuit.

Once the circuit is located, a conventional multi-meter can be used to pin point the fault.

## 3.4 TRACING DC EARTH FAULTS

### 3.4.1 Fault Finding

To ensure that repairs are carried out under safe conditions, it is essential that all the DC station and unit boards are fitted with bus-section switches. Before carrying out any repairs it is recommended that all boards are physically inspected and checked to see that each outgoing circuit is backed up by both a main and a back up DC supply.

In certain cases a decision may have to be made whether to have a switched outage on the affected machine or whether to live with the problem until a machine outage.

It is essential that the faulted DC circuit is isolated before any further tracing is done to avoid the possibility of losing important plant.

To protect electronic components from damage, a low voltage multi-meter shall be used to trace faults. It is not advisable to use a 500 V insulation tester. If this is unavoidable, all electronic components and relays shall be disconnected before any tests are carried out with the insulation tester.

Once the fault has been cleared and the circuit re-checked with a multi-meter, the DC supply can be re-instated. Both the EF100 and EL DeC relays must then be checked to ensure that they have reset and that all alarms are clear throughout the station or HV yard.

Before switching DC supplies off for brief periods, it is essential to ensure that equipment will not operate to trip important plant or a unit generator. All DC circuits should be checked during a general outage (GO) to ensure that when the DC circuit is isolated for brief periods, equipment does not operate to trip important plant.

Before commissioning DC circuits after a GO it is essential to check that all earth faults have been cleared.

### 3.4.2 Typical Example of the Fault Finding Sequence

This example is based on a Power Station where EL DeC relays are fitted to the end points of certain of the more important (risky) circuits of the DC station and unit boards and to both sides of each of the MV boards, as shown in **Figure 3**. It is assumed that the EF100 relays are set at 20 mA and that all EL DeC relays are set at 12 mA.

The following cases are considered:

#### 3.4.2.1 EF100 Alarm

If the EF100 relay alarm operates, check whether any EL DeC relay alarms are operative. This can either be done by contacting the respective unit control desks (if alarms are cabled to the control rooms), or by inspecting each board and remote circuit where EL DeC relays are installed.

#### 3.4.2.2 EF100 Alarm and No EL DeC alarm

If there are no EL DeC relay alarms, then one or more of the following faults may be present at the same time:

a. On the supply side of the DC Station Board,

b. On the DC Station Board,

c. On any of the unprotected DC Station Board outgoing feeders,

d. On any feeder downstream of an EL DeC relay (earth fault leakage less than the EL Dec relay sensitivity).

Sequential isolation of the circuits in 3.4.2.2(c) will either locate some of the faulty circuits (this will be indicated by the EF100 alarm clearing) or eliminate case 3.4.2.2(c). Alternatively use a portable test instrument as explained in 3.4.1. If the EF100 relay does not clear by carrying out this procedure and if there is reason to discount 3.4.2.2(a) and 3.4.2.2b), then no further action is required as each individual remaining leakage is smaller than 12 mA.

#### 3.4.2.3 EF100 Alarm and EL DeC Alarm

a. If the EL DeC relays that operate are on a common radial path from the battery, the fault is located downstream from the remotest relay, otherwise,

b. there is a fault on each feeder where the relay operates.

In either case, sequential isolation of the circuits supplied by such feeders will locate the faulty circuit/s. This will be indicated by the relay resetting and its buzzer sounding (as explained in 3.3.2). Alternatively use a portable test instrument as explained in 3.1.1

#### 3.4.2.4 EL DeC Alarm and No EF100 Alarm

If one or more EL DeC relay operates, and the EF100 relay does not (this is possible as it is assumed that the EF100 is set higher than the EL DeC), the fault can be traced by the procedure under 3.4.2.3.

### 3.4.3 Ambiguous Alarm Indication

The following unlikely circumstances can give rise to ambiguity:

When the earth fault current is close to the pick-up level of the EL DeC relay, some EL DeC relays on the radial fault path may pick-up and some may not due to the 5 mA tolerance on the relay setting.

When there is more than one earth fault, then either:

a. the faults are on the same polarity, in which case the fault current detected by an upstream relay is higher than the current detected by the downstream relay. While the relay upstream (possibly a EF100) will operate, it is possible that none of the downstream EL DeC relays will. This case was considered under 3.4.2.2(d) or,

b. the faults are of opposite polarity, in which case the fault current detected by an upstream relay is lower than the current detected by the downstream relay. The downstream relays will operate but the upstream relays may not operate, moreover, removal of a fault may cause the relay upstream (possibly a EF100) to suddenly pick-up as illustrated in **Figure 4**.

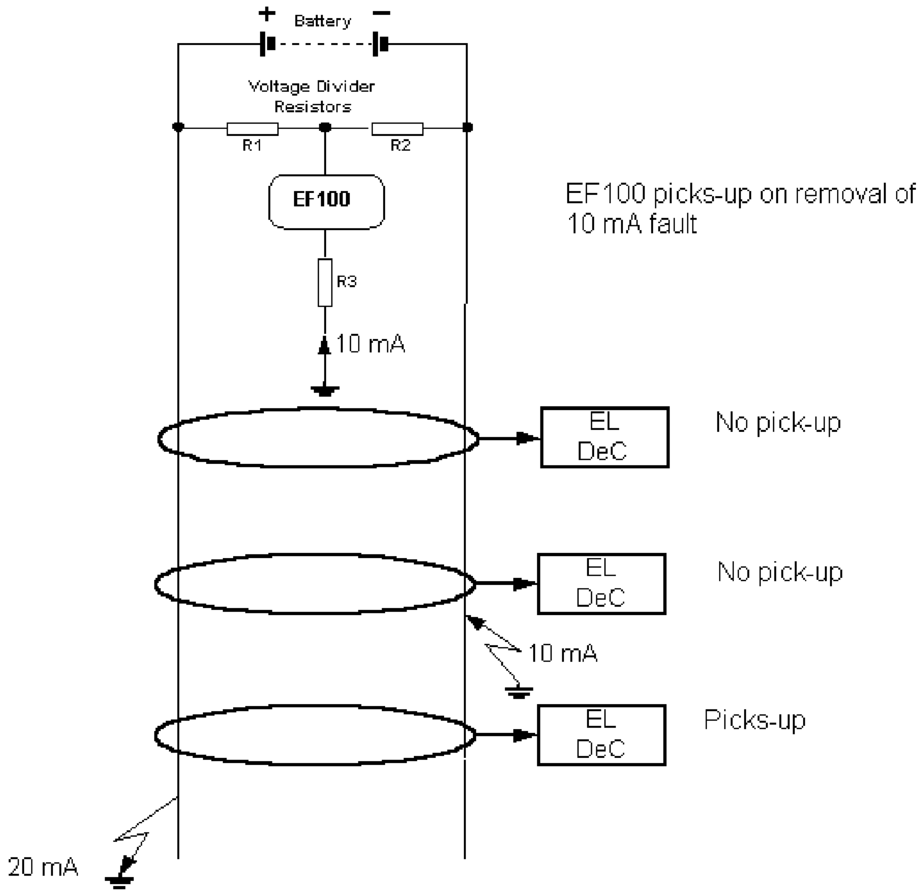


**Figure 4: Ambiguous Alarm Indication**

## 4. AUTHORISATION

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## 5. REVISIONS

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## 6. DEVELOPMENT TEAM

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

- None

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