Title: Earthing High Voltage Apparatus

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Associated Documents:
- APS-P-SHE-02-001 – APS Safety Rules (E&M)
- APS-I-SHE-02-009 – High Voltage Switching
- APS-I-ENG-09-004 – Identification and Inspection of Portable Earthing Devices

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1 INTRODUCTION/PURPOSE

This APS Instruction applies the principles established by APS Safety Rules (E&M) to give guidance on the earthing arrangements to achieve Safety from the System for personnel to work on High Voltage (HV) Apparatus at the ACME power plant.

2 SCOPE

Earthing of High Voltage Apparatus is carried out as part of the safety precautions to protect persons working on or testing such Apparatus against the effects of inadvertent re-energisation and induced voltages. The protection afforded by earthing is dependent upon the combination of:

(i) The efficiency of the connection of Primary Earths and their capability to carry the fault current until the electrical protective devices operate.

(ii) The speed of operation of electrical protective devices in service called upon to operate in such circumstances.

(iii) The system voltage, voltage gradient to the point of earthing and the fault level at the point of work.

3 DEFINITION

Definitions used within this APS instruction are as defined in Part D of APS Safety Rules (E&M).

4 RESPONSIBILITIES

Responsibilities are defined in Part C of APS Safety Rules (E&M) - Responsibilities of Persons.

All Authorised Persons and Senior Authorised Persons shall ensure that High Voltage switching is carried out in accordance with this Instruction.

All APS staff and Contractors shall adhere to the instructions laid down in this instruction whenever working on or close to the equipment.
5 INSTRUCTION

5.1 Identification of High Voltage Apparatus

All HV apparatus must be clearly identifiable, particular attention should be made in the 500kV substation where a mixture of EGAT numbering system and Mitsubishi numbering system (MNS) exists.

5.2 Dangers and Hazards

The main Dangers and Hazards to personnel applying earths to HV Apparatus are electric shock, burns or falling, arising from:

(i) The application of earths to Live HV Apparatus.

(ii) Badly connected or insecure Earthing Devices.

(iii) The incorrect sequence or method of application or removal of Portable Earths.

(iv) The inadvertent earthing of Live HV Apparatus by the loss of control or difficulty in the handling of portable earthing equipment.

5.3 General Earthing Requirements

The requirements detailed below must be met with regard to the earthing of HV Apparatus:

5.3.1

Primary Earths must be applied within the Isolated zone and, where reasonably practicable, be positioned between the point of work and all point(s) of isolation excluding Low Voltage (LV) connections but including, where applicable, the point of isolation from common neutral earthing equipment. Where the points of isolation of HV Apparatus include LV connections and the HV Apparatus can, during the course of the work, become disconnected from the rest of the Earthed HV Apparatus in the Isolated zone, a Primary Earth must be applied to the HV Apparatus or the work carried out in accordance with an Approved procedure, if inadvertent energisation could cause Danger.

5.3.2

Primary Earths must be of adequate cross-sectional and be efficiently connected between earth and the Isolated HV Apparatus so as to discharge safely the resultant fault current due to any inadvertent energisation. Portable Primary Earths must have a cross-section of not less than 65 mm$^2$ (0.1 in$^2$) copper equivalent, except in the case of electrostatic precipitators where a minimum cross-section of 25 mm$^2$ (0.04 in$^2$) copper equivalent may be used.

5.3.3

Where possible a specially provided earth switch or fixed Earthing Device capable of making short-circuit current should be used to make the first Primary Earth connection.
5.3.4
Where it is not reasonably practicable to apply Primary Earths between the point of work and the points of isolation, they may be placed in an alternative position so as to have a similar electrical effect to that which would occur if they were placed between the point of work and the points of isolation. Such a position could be:

(i) on a permanent connection teed between the point of work and the point of isolation at a distance not exceeding 9 m (30 ft) from the tee point, or

(ii) at a point not more than 9 m (30 ft) beyond the point of work from the point of isolation, or

(iii) as dictated in an alternative Approved procedure.

5.3.5
When compliance with the above requirements does not give adequate protection from induced voltages, Drain Earths must be applied in accordance with an Earthing Schedule (Appendix I).

5.3.6
It is not necessary to earth every part of the HV Apparatus within an Isolated zone provided that the requirements of the Power Generation Services Safety Rules (Electrical and Mechanical) and this APS Instructions have been met.

5.3.7
Subject to the provisions of 5.3.13, the application and removal of Primary Earths, including the closing and opening of earth switches and fixed Earthing Devices when used as Primary Earths, must be carried out by the Authorised Person who has received instruction from the appropriate Control Person or Senior Authorised Person, or in the case of a Person under instruction, carried out in accordance with the requirements of APS/I/SHE/02/009 "High Voltage Switching". Under the terms of a Sanction for Test, however, the recipient of the Sanction for Test may remove or replace those Primary Earths defined on the Sanction for Test.

5.3.8
Portable Earthing Devices should be examined quarterly and the results of such examination recorded as identified in APS Instruction APS/I/ENG/09/004 "Identification and Inspection of Portable Earthing Devices". They should also be examined immediately before use by the Person responsible for the application of such Earths. At any time, a defective Portable Earthing Device must be withdrawn from service forthwith.

5.3.9
The Senior Authorised Person responsible for the earthing should take all reasonably practicable steps, including making arrangements with the Control Person for switching out additional equipment if necessary, to ensure that earthing by means of a Portable Earth using an Approved pole is carried out in situations where clearances from adjacent Live HV Apparatus are adequate to prevent Danger should control of the pole be lost.
5.3.10
As an additional precaution the Senior Authorised Person in charge of applying Portable Primary Earths should, before doing so, ensure so far as is reasonably practicable that adequate protective devices are in service on busbars and circuits in the vicinity of the earthing operation in case of inadvertent earthing of adjacent HV Apparatus.

5.3.11
Where Portable Primary Earths are to be used, care should be taken to ensure that the points at which the Portable Primary Earths are to be applied to the HV Apparatus are of adequate capacity so as to safely discharge the resultant fault current due to any inadvertent energisation after they have been secured in position.

5.3.12
The points of application of Portable Primary Earths should not be such as to inhibit the operation of any protective devices or other ancillary equipment which is in service and which may be required to operate.

5.3.13
Ideally, the Primary Earths through which the HV Apparatus is Earthed will be visible from the point of work thereby giving positive evidence of Safety from the System, but this is often difficult to achieve in practice.

If the Primary Earths are not close to and visible from the point of work, there must be no reasonable doubt that the correct Apparatus will be worked on. If there is any doubt concerning the identification of Apparatus which has been Isolated and Earthed at a remote point, an Approved voltage indicator must be used to verify that the conductors are not Live and local Primary Earths must be applied.

In some cases it may be necessary to expose circuit conductors under controlled conditions in order to establish a point of application for local Primary Earths. This must be carried out by or under the Personal Supervision of a Senior Authorised Person or under the terms of a Safety Document, and no person must be placed at risk from the potentially hazardous circuit.

5.3.14
Portable Drain Earths must have a cross-section of not less than 25 mm$^2$ (0.04 in$^2$) copper equivalent.

5.3.15
Drain Earths in connection with a Permit for Work must be applied and removed by a Competent Person in accordance with the requirements of the Earthing Schedule.

5.3.16
Drain Earths in connection with a Sanction for Test must be applied and removed in accordance with the requirements of the Earthing Schedule by an Authorised Person or a Person under the Personal Supervision of an Authorised Person.
5.3.17
When either the Primary Earths or Drain Earths would prevent access to the points of work, the HV Apparatus on which work is to be done must be efficiently connected to earth at the nearest points to the points of work where access can be obtained. Where Drain Earths are applied at the point of work, they may be removed in turn when work is to be done but each earth so removed must be replaced before another earth is removed.

5.3.18
When HV Apparatus has been disconnected from all supplies and bodily removed from its service position, the use of Primary Earths on that HV Apparatus is not necessary, provided that the HV Apparatus is electrically discharged.

5.3.19
When contractors are working in High Voltage enclosures where Drain Earths are required and which may be applied or moved by the contractors within a defined safe working area, the Drain Earths may be issued to the contractor and recorded on his Permit for Work. At the discretion of the Senior Authorised Person issuing the Permit for Work, these Drain Earths may be issued to the APS Competent Person who may be supervising the work and must then be recorded on his Permit for Work.

5.3.20 Portable Earths
- Whenever reasonably practicable, before commencing to apply Portable Primary Earths, an Approved voltage indicator shall be used to verify that conductor to earthed is not Live at System voltage. The voltage indicator shall be tested immediately before and after use on an approved voltage proving unit.
- Portable Earths shall be applied to and removed from conductors using Approved device.
- Portable Earths shall only be applied in any cell or cubicle when all exposed conductors are Isolated from the System.
- When a Portable Earths is to be applied, the earth end of each earthing connection must be attached to metal which is electrically bonded to earth, before the conductor end clamp is applied. When multiple (three phase) earthing connection are to be used as such a manner than two or more earth clamps will be close proximity to each other, the earth end clamps of all these earthing connection must be attached before any of the conductor end clamps are applied.
- When Portable Earths is to be removed, the conductor end clamp connection must be removed before the earth end clamp. When multiple (three phase) earthing connection have been used such that two conductor end or earth end clamps are in close proximity to each other, the conductor end clamps of all these earthing connections must be removed before any of the earth end clamps. At no time shall the conductor end clamp of a Portable Earths be allowed to remain connected when its earth end clamp has become detached.
- If such a disconnected Portable Earth is only the earth on that conductor at that point, an additional Portable Earth shall be connected between earth and that conductor before the detached Portable Earth’s conductor end clamp is removed. In all cases, before the earth end clamp is re-connected, the conductor end clamp must first be removed.
5.3.21
If breaking a Primary Earth connection should be made, the integrity of application of earthing switch must be maintained by applying a Portable Primary Earth before breaking the connection.

5.3.22
All of the Portable Earth and Approved tools are identified with unique identification number.

5.3.23
An Senior Authorised Person with High Voltage authorisation has responsibility for controlling the issue, receipt, return and storage all of the High Voltage portable earths applied at the ACME power plant. The High Voltage portable earths and Approved tools will be available at:

- Electrostatic Precipitator (EP) switchroom, the portable earths are to be applied to the EP discharge electrodes.
- Unit 11kV switchroom, the portable earths are to be applied on any conductor which is under maintenance, if fixed earth has been removed for maintenance purposes.

5.4 Application of Primary Earths to Transformers

- Transformers will require to be Earthed between the windings and all HV point(s) of isolation, but earthing is not required on the LV sides of transformers.
- When a generator transformer is connected to a generator turning on barring gear, care must be taken that the continuity of the earth path through the windings is maintained. If work on the tap changer or windings is undertaken, any point of disconnection should first be bridged. This is to avoid an induced decaying High Voltage being produced across the disconnection due to the collapse of a magnetic field associated with any small circulating current in the transformer windings.

5.5 Application of Primary Earths on 500kV GIS Switchgear

5.5.1 System Overview

Modular phase segregated Gas Insulated Switchgear including Circuit Breaker, Disconnector Switches, & the Earth Switches. Within the modular Gas Insulated Switchgear (GIS) unit there are two different types of earth switches installed. The first type is a Fault Making (fast acting) earthing switch (FES), these are only fitted on the Line circuits. They have a spring snap action mechanism with motor drive for re-charging spring. This earthing switch has a facility for manual operation should the motor drive fail. The second type is a manually operated earth switch (ES) which is designed to be applied to facilitate working on maintenance activities. All earth switches have a local mechanical ON/OFF indicator.

5.5.2 Interlock System

The earth switches utilise an electro/mechanical interlock system to prevent insertion of the manual operating handle. The logic relies on feedback from voltage relays and position of circuit breaker and disconnector switches.
5.5.3 Application of Earthing Switch

Normal application of Fault Making (fast acting) earthing switch (FES) is via the Local Control Panel. Should this fail to operate the earth switch can be manually applied with the crank handle. Integrity of application is maintained by isolation of the drive motor MCB and the mechanical locking pin arrangement. There is also a facility to lock the operating door to prevent any interference with the operating mechanism.

The "maintenance" earth switch (ES) can only be manually applied with the crank handle and integrity of application is maintained by the mechanical locking pin arrangement. There is also a facility to lock the operating door to prevent any interference with the operating mechanism.

5.6 Application of Primary Earths on 11kV Switchboards

5.6.1 System Overview

The common design concept of all 11kV switchboards at ACME includes a combination of cubicles housing vacuum circuit breakers and voltage measurement devices.

Earthing trucks are provided for the busbar and circuit arrangements.

Note: earthing trucks do not have a locking facility.

5.6.2 Interlock System

A mechanical interlocking system is used to prevent accidental application of the wrong earthing truck.

5.6.3 Application of Earthing Truck

Manual application of the earthing truck can only be made once the Vacuum Circuit Breaker (VCB) carriage has been removed from its cubicle. The earth truck inserted into the racked in-service position using a special application lever found in each switchroom.

The closing of the earthing truck VCB can only be done at local, once it is in the in-service position with its umbilical cable connected it can be closed using the dedicated "Earth Switch Close" push button on the switchgear panel front. The earth switch can only be opened by unlocking the VCB cubicle front door and pushing the manual open button on the earth truck carriage.

5.7 Application of Earths on Electrostatic Precipitator (EP)

5.7.1 System Overview

There are two kinds of earthing devices applied on EP system:

- An earthing device is attached on each Transformer/Rectifier (Discharge Electrode) as a fixed Earth Switch which is lockable in the open or closed position.
- Earthing device (grounding rod) is attached onto the discharge electrode as a Portable Earth during maintenance.
5.7.2 Interlock System
There is no interlock system.

5.7.3 Application of Earthing Arrangements
When the Transformer/Rectifier unit has been isolated its associated earth switch can be applied and locked.

If internal access to the electrostatic precipitator is required portable earths (grounding rod) should be applied to the discharge electrode at each point of access.
6 CONTROL OF RECORDS

All records covered within this APS instruction provide evidence of the ongoing operation and should be properly organize and managed.

All records must be readily available for scrutiny and audit.

Records should be stored where possible within the APS Filing System maintained by Document Control.

7 REVIEW AND AUDIT

All APS Procedures and Instructions will be subject to review every two years unless the need arises before the planned review date. Additionally, this instruction will be subject to audit in accordance with APS/P/SHE/03/003 – Safety, Health and Environment Audit and Review.

Any inaccuracies or omissions in this instruction should be notified to the instruction owner immediately.
 Appendix I
Earthing Schedule
**ACME POWER PLANT**

**APS SAFETY RULES (E&M)**

**EARTHING SCHEDULE**

Document No. ..................

<table>
<thead>
<tr>
<th>Plant/Apparatus/Circuit:</th>
<th>……………………………………………………………………………………………………</th>
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</thead>
<tbody>
<tr>
<td>Associated Safety Document Number:</td>
<td>…………………………………………………………………………………………</td>
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</table>

**NOTE:** Work must not commence on any stage until the earthing requirements for that stage have been completed.

<table>
<thead>
<tr>
<th>Stage No.</th>
<th>Work/Testing Description</th>
<th>Drain Earths</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Location</td>
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<td>Number</td>
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**Sketch/Remarks**

- Total number of Portable Earths required and issued
- Fixed Earthing Devices to be used
  - (Use should be specified)
  - (on Work/Testing)
  - (Description)

**Issue**

Signed............................................................. Time ......................... Date.......................... Senior Authorised Person

**Cancellation**

Signed............................................................. Time ......................... Date.......................... Senior Authorised Person