# Customer Guidance Document: Installation of RFCTs

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# Final Approval

Final approval required by an Independent Health and Safety Consultant and EA Technology CEO.

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| Final | 23 August 2018 | Issue 1 |  Robert Davis (EA Technology, CEO) |
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# Document Summary

This document is intended for customers wishing to install RFCTs fitted around the earth wire within cable chambers. It provides guidance to ensure Health and Safety risks have been considered and appropriate mitigation is recommended.

*This document sets forth the recommended minimum requirements for safe installation of the RFCTs. This document does not replace nor supersede local, state and federal safety laws rules and regulations nor your company safety practices, all of which must be observed during installation. In the event of any conflict with those requirements, the safer practice is to be applied. EA Technology provides these requirements as an aid to the customer. EA Technology expressly disclaims any and all liability for the safety of the installation, which remains the sole responsibility of the qualified safety personnel of the customer staff and any Authority having jurisdiction.*

# Contents



## Appendices

# 1. Background

This document is intended for customers wishing to install RFCTs fitted around the earth wire within cable chambers. It provides guidance to ensure Health and Safety risks have been considered and appropriate mitigation is recommended.

# 2. Pre-Installation Audit

It is recommended the customers complete a site and switchgear assessment to ensure a suitable technical and safe installation is viable and assess the potential risk associated with specific sites and switchgear. The audit should be completed by a competent person in accordance with the customer's Safety Rules. The audit should include:

### 2.1.1 Assessment of substation condition

- Cleanliness
- Humidity
- Temperature
- Environmental control
- Building type (Brick, concrete, GRP, Metal etc) and the condition and integrity of the substation

### 2.1.2 Assessment of Switchgear Condition

- SF6 gas pressure gauge indicating healthy gas pressure (Where applicable)
- Perform a quick PD survey prior to operation of the switchgear
- Ensure all covers are fitted correctly before operation
- Visually check for signs of electrical or mechanical stress to the equipment
- Listen for any audible signs of stress within the switchgear

### 2.1.3 Isolation and Earthing

- The customer shall isolate and earth the switchgear and prove dead at the point of working in accordance with their safety rules.

### 2.1.4 Earthing of the sensors

EA Technology recommends that the outer screen conductor of the RFCT cable be attached to earth to improve safety and reduce induced currents. The EA Technology equipment does not provide a solid connection to earth. There are many ways the screen of the coaxial cable can be connected to earth, two of which are described below:

#### Grounded bulk head connector

A feed through coaxial bulk head can be permanently mounted to the metal work of the enclosure. The bulkhead can then be separately tied to earth using a suitable separate earth cable to a dedicated Earth point within the switchgear. The following, Figure 1 is an example of a test box with such a bulk head adaptor where the black metal plate is earthed on the rear side through the back of the box to the main

earth bar in the switchgear. The feed through coaxial connectors used on the bulkhead must be fitted in such a way that the outer of the connector is connected to the earthed chassis plate.

*Figure 1 Feed through bulkhead*

### Modified RFCT cable

Where the mounting of bulkheads is not feasible the RFCT can be connected with a modified coaxial cable that has a separate earth lead attached to the outer screen at the RFCT end. This can then be connected directly to a local earth point within the switchgear.

### 2.1.5 Earthing arrangement within the cable compartment

To enable safe operation of internal sensors, it must be confirm, it must be confirmed that the HV ground wire from the cable screen can withstand fault current until the protection operates. This should be determined in accordance the latest edition of relevant National Standard (for example in USA National Electrical Code NFPA 70, Appendix II). Visual verification and measurement of the earthing arrangement should be made to confirm it meets the requirements stated in relevant National Electrical Code.

If national standards are not readily available as a minimum recommendation all earth strands from a conductor should be brought out to a common point and crimped together. Any additional earth wire added from this point to the main Earth Bar of the cable compartment must be of at least the same cross-sectional area as the sum of all the strands brought out from the cable screen.

**If the earthing arrangement is not compliant, then the use of internally installed RFCTs is not recommended until the issues have been rectified.**

### 2.1.6 Minimum Acceptable Condition of the HV Chamber

The HV chambers should be visually inspected to ensure they are in a suitable condition to enable safe and reliable installation of the sensors.

As a minimum the chamber should be dry, free from excessive contamination (although this is acceptable if it can be adequately cleaned), all connections should be secure and free from significant mechanical damage. Evidence of normal age degradation or the on-set of partial discharge activity is acceptable if the condition meets the above stipulation.

**If this is not the case, then the use of internally installed RFCTs is not recommended until the issues have been rectified.**

### 2.1.7 Minimum Clearances

When installing sensors within an air insulated cable compartment not utilising fully screened touch safe separable type connectors. Internal sensors should only be fitted if the required minimum clearances stated in Appendix I can be maintained.

Where fully screened separable type connectors are used the sensors should be fitted around the earth strap as far as practicable away from the connector boots.

**If this is not the case, then the use of internally installed RFCTs is not recommended until the issues have been rectified.**

### 2.1.8 Installation Verification

Photographic evidence of the switchgear condition and dimensions should be recorded for future use.

# 3. Installation Considerations

The purpose of this section is to assess the risk associated with an internally positioned sensor.

### 3.1.1 Sensor location

If the pre-installation audit indicates that there is potential to permanently install sensors in an acceptable safe manner then an assessment of the technical benefits of various sensor positioning, should be completed. The use of internal sensors should be an improved technical solution compared to external sensors such as:

- Improved accuracy of measurements
- Additional protection from environmental factors
- Additional mechanical protection
- Additional components can be monitored
- Data can be more appropriately utilised and interpreted to provide improved outputs regarding asset condition and recommended asset management actions
- In addition, it is recognised customers' drivers and preferences should be considered.

### 3.1.2 Clearances

#### Air insulated cable compartment

When installing sensors in an air insulated cable compartment the minimum clearance distances between live conducting parts and the sensors stipulated in Appendix I must be maintained.

#### Fully Screened separable type connectors

Where fully screened separable type connectors are used within the cable compartment the sensors should be mounted as far as practicable from the connector boot around the earth screen wires. Note on these type of systems the sensor must be placed around the cable earth screen wires and not the drain earthing lead associated with the connector system, see Figure 2.

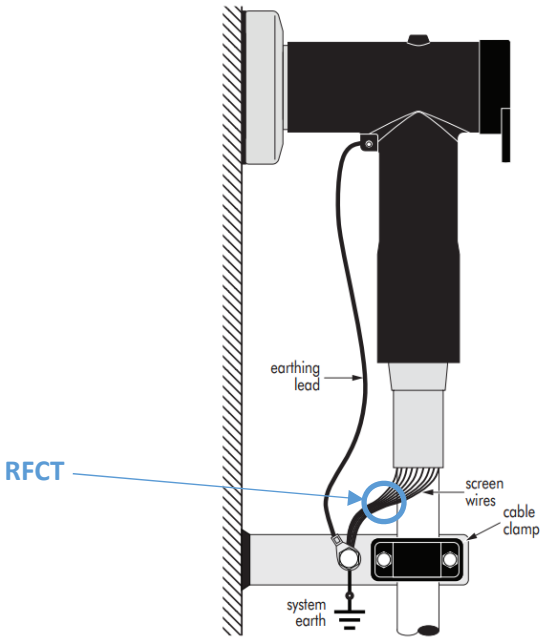


*Figure 2 Separable Connector System*

### 3.1.3 Routing of the sensor cable

1. The sensor cable route needs to be considered, it should not impinge on other components or be an excessive length – the external node position should be considered. Any cabling installed needs to meet the relevant international cabling standards.

2. Where possible the sensors shall be secured in place to prevent additional mechanical loading on the installed cabling.

3. The risk of components / debris falling onto the sensor should be considered, wherever possible the sensor should be positioned such that contamination, or a single mechanical failure of a fixing does not impinge on the sensor.

4. All LV cabling must be kept as far from the HV terminations as practicably possible maintaining minimum clearance distances outlined in Appendix I.

5. All LV cabling should be routed in a way that it is not possible for the cabling to fall upon any live HV components within the cable compartment. Where possible route the cabling away from live exposed components and along edges of the cable compartment.

6. Where cabling is to be routed around the hinge of the door it should be mechanically supported on both sides of the hinge and sufficient slack provided to enable the door to fully open. If possible, additional sleeving should be placed around the cables.

7. Consult the manufacturers documentation to confirm if there is a preferred method of routing LV cabling within the HV cable compartment utilise this method where possible.

8. On modern switchgear there is often a dedicated trunking route behind a metallic cover for the routing of CT, VT and ancillary component wiring within the cable compartment. Where this is available, and space permits it should be used to route the LV wiring within the HV cable compartment.

9. The cable length shall be secured to ensure no load is present on cables and excessive lengths of cabling shall be secured within the trunking.

10. Determine if the HV cable box is internally Arc Rated. If this is the case then any additional drilling of the cable compartment to facilitate the routing of the LV cabling needs to be confirmed by the switchgear manufacturer.

11. All drilling debris shall be removed from the cable box.

12. Given the above considerations the sensor should be positioned to achieve the maximum PD detection of the various components.

### 3.1.4 Hub to laptop connection

When connecting a personal computer (PC or Laptop) to either a UltraTEV Monitor (UTM) hub or Cable Data Collector (CDC) consideration should be given to the means of connection between the devices. If the connection is to be connected for longer than a few minutes, it is recommended to use an Ethernet to fibre converter and fibre optic cable between the two devices to provide electrical isolation.

### 3.1.5 Function test of sensors

Once installed, but prior to energisation and closure of the panel a functional test of the RFCT's is recommended. The test will inject a current pulse of a known size though the RFCT and detection will be confirmed on the installed measurement system or a separate UltraTEV Plus[2]. The purpose of this test is to confirm continuity of the wiring between the RFCT and the measurement device and correct phase identification.

### 3.1.6 Final HV Chamber checks

Visual examination of the final installation to ensure no physical damage has occurred, components are secure, and all contamination is removed.

### 3.1.7 Warning and Security signs

External warning signs similar to those shown below in Figure 3 should be fitted on the cable box cover plate to communicate that the installation contains permanently installed sensors that are not to be tampered with. These shall be placed in a clearly visible position.

**⚠Caution ⚠**

**This switchgear contains Radio Frequency Current Transformers (RFCT) which are critical to personal safety.**

**Please refer to the site senior authorized person (SAP) for clarification prior to opening compartment.**

*Figure 3 Example Warning Sign*

### 3.1.8 Personnel and Installation Documentation

The installation should be completed by appropriately authorised and competent personnel, in accordance with the customers safety rules.

For each asset installation the installer should complete appropriate installation documentation and hold on record; an example is given in Appendix III.

A quick start guide is included in Appendix IV for reference.

### 3.1.9 Ongoing Management of Installations

The customer's documented maintenance procedure for the associated switchgear should be amended to recognise the internal sensors are fitted, clearances will be maintained, and the integrity of the sensors upheld.

The customer should have adequate control measures in place to ensure the continued safe operation of the system including:

1. Appointment of competent persons to work on the system.
2. The connection from the hub to the laptop when working for prolonged periods shall be via means of an Ethernet to fibre optic converter to ensure electrical isolation.
3. The customer's documented maintenance procedure for the associated switchgear should be amended to recognise the presence of internal sensors and that clearances will be maintained, and the integrity of the sensors secured.
4. The customer should ensure that the warning and security notices are intact and have a written procedure for the management of the installation.
5. The 'Installation Documentation' Part 1 (example in Appendix III) should be completed for each installation. The installations shall be in accordance with the approved procedure as outlined in this document and the Quick Installation guidelines (Appendix IV).
6. During multiple cable box installations external connections to the sensors inside HV compartments should be the final activity.

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# Appendix I Minimum HV Clearance Guidelines

When installing RFCT sensors around earth straps, care must be taken to ensure that an installation meets the minimum HV clearances between all three sensors (the 'sensor-to-sensor' clearances) and from the sensors to the HV terminals/conductor/busbar (the 'sensor-to-HV') clearances.

The minimum recommended clearances are based on IEC 61936-1 POWER INSTALLATIONS EXCEEDING 1 kV AC –Part 1: Common rules (Table AI.1). EA Technology has used the most onerous condition (i.e. outdoor equipment and highest rated impulse withstand voltage) and applied a 'safety factor' of x2 in recognition that the breakdown voltage can vary with humidity, airborne contamination and the geometry of the components.

**EA Technology's Recommended Minimum 'Sensor-to-HV' High Voltage Clearances:**

- 240 mm for 6.6 kV
- 320 mm for 11 kV
- 320 mm for 14.8 kV
- 520 mm for 20kV
- 640 mm for 33kV
- Refer to appropriate international standards for voltages in excess of 33kV

**Table AI.1 IEC 61936-1 Standard – Minimum Clearances in Air**

| Nominal voltage of system | Highest voltage for equipment | Rated short-duration power-frequency withstand voltage | Rated lightning impulse withstand voltage [a] | Minimum phase-to-earth and phase-to-phase clearance, *N* [c] | |
|---|---|---|---|---|---|
| $U_n$ r.m.s. | $U_n$ r.m.s. | r.m.s. | 1,2/50 µs (peak value) | Indoor installations | Outdoor installations |
| kV | kV | kV | kV | mm | mm |
| 3 | 3,6 | 10 | 20 | 60 | 120 |
| | | | 40 | 60 | 120 |
| 6 | 7,2 | 20 | 40 | 60 | 120 |
| | | | 60 | 90 | 120 |
| 10 | 12 | 28 | 60 | 90 | 150 |
| | | | 75 | 120 | 150 |
| | | | 95 | 160 | 160 |
| 15 | 17,5 | 38 | 75 | 120 | 160 |
| | | | 95 | 160 | 160 |
| 20 | 24 | 50 | 95 | 160 | |
| | | | 125 | 220 | |
| | | | 145 | 270 | |
| 33 | 36 | 70 | 145 | 270 | |
| | | | 170 | 320 | |

# Appendix II Earthing Requirements

Example of Earthing Requirements (Extracts from NFPA 70 2017 (also known as National Equipment Code for the USA)

**Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems**

| Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil) | | Size of Grounding Electrode Conductor (AWG/kcmil) | |
|---|---|---|---|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum[b] |
| 2 or smaller | 1/0 or smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | 3/0 | 250 |

Notes:
1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
[a]This table also applies to the derived conductors of separately derived ac systems.
[b]See installation restrictions in 250.64(A).

**Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems**

| Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) | | Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil) | |
|---|---|---|---|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum |
| 2 or smaller | 1/0 or smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | See Notes 1 and 2. | |

Notes:
1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.
2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.
3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.
4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Extracts from NFPA 70 2017 (also known as National Equipment Code)

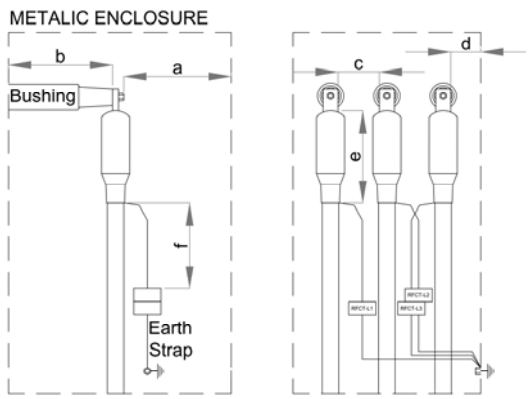
# Appendix III Installation Documentation for Internal RFCTs

All the following points must be completed for each Panel/Cable termination by a Competent person working in accordance to local safety standards and this method statement. This document should be kept current and updated following any activity within the cable compartment.

### Part 1: Initial Installation

| | | | |
|---|---|---|---|
| **Substation Name** | | | |
| **Engineers Name** | | | |
| **Switchgear Information** | | | |
| Manufacture | | | |
| Model | | | |
| Serial Number | | Year of Manufacture | |
| Voltage rating (V) | | System Voltage (V) | |
| Short Circuit Rating | | Current Rating (A) | |
| Earthing and Protection | State standard to which the system is compliant | | |
| **Cable Box Information** | | | |
| Cable box / Cable identification | | | |
| Number of cables per phase | | Three core / Single core | |
| Cable Insultation | XLPE / PILC / EPR / Other (please state) | | |

**Clearances (All dimensions in mm)**




Minimum clearance distances permitted when using air insulated terminations.

240 mm for 6.6 kV
320 mm for 11 kV
320 mm for 14.8 kV
520 mm for 20kV
640 mm for 33kV

| | L1 | L2 | L3 |
|---|---|---|---|
| a | | | |
| b | | | |
| c | | | |
| d. (Minimum) | | | |
| e | | | |
| f | | | |

| | |
|---|---|
| Confirm f is greater than applicable minimum clearance distance and is not less than distances a, b, c and d | |

CT Serial Number

| L1 | L2 | L3 | Common Earth (L1, L2, L3) |
|---|---|---|---|
| | | | |

| **Photographic documentation** | **File** |
|---|---|
| Cable box warning sticker fitted | |
| CT Wire routing | |
| Cable Compartment Post installation showing clearances | |
| **I confirm the information submitted above is correct:** | **Print:** **Sign:** |
| **Date:** | |

# Appendix IV Quick Install Guide

## RFCT Quick Install Guide

The following is to be used as a guide when installing RFCT's as part of a permanent installation. The document is to be used to assist competent trained personnel with the installation of the RFCT's. The document does not replace local standards or procedures. EA Technology do not accept any responsibility for the correct installation of the RFCT's when installation has not been verified by our own Engineers.

This document has been read and all guidelines followed in the installation of the RFCT's supplied.

Name (Print and sign)..... Date..... Company.....

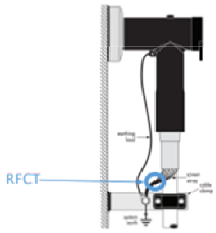
**1**

1. Visually Inspect the RFCT for any signs of damage.
2. Visually inspect all coaxial cables and connectors for any signs of damage.
3. *Where possible connect the RFCT with the* coaxial cable to be used to an UltraTEV plus2 and use a known test source to confirm integrity of the CT cable configuration.

**2**


1. Permanent fitting of RFCT's within a cable compartment should only performed when all HV cables within the cable box have been isolated and earthed.
2. It is the responsibility of the site Senior Authorized Person (SAP) to ensure all equipment to be worked upon has been made DEAD and control the issue of permits to work within the cable compartments.
3. Confirm the cable box is clean, dry and suitable for installation of RFCT's

**3**

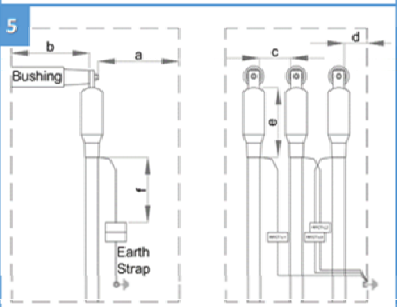



1. Locate the Earth straps upon which the RFCT is to be fitted.
2. Ensure the RFCT is placed around the main screen earth and not any accessory drain earth cables.
3. Where the Earth screen is extended. Ensure the cross-sectional area of the extension cable is equal to or greater than the sum of the cross-section of all the screen wires.

**4**

1. Clamp the RFCT around the Earth strap.
2. Ensure the arrow on the RFCT is pointing in *the direction of the earth strap to the near*est point of Earth.
3. *Secure the RFCT such that it is not present*ing a mechanical load to the earth strap or other accessories within the cable box.

**5**




1. Record minimum clearance distances: a, b, c, d, e & f, within the cable box.

**6**

**EA Technology's Recommended Minimum 'Sensor-to-HV' Clearances for air insulated terminations:**

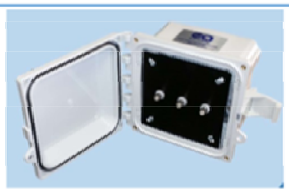
240 mm for 6.6 kV
320 mm for 11 kV
320 mm for 14.8 kV
520 mm for 20kV
640 mm for 33kV

1. Confirm minimum clearance distances outlined above are maintained.
2. Confirm f is greater than applicable minimum clearance distance and is not less than distances a, b, c and d.

**7**

1. *Connect the coaxial cable to the RFCT.*
2. Route the coaxial cable out of the cable box using manufacturers recommended routing where possible.
3. If the HV cable box is internally Arc Rated, drilling of the cable compartment to facilitate routing of the coaxial cabling must be confirmed by the switchgear manufacturer.
4. Ensure minimum clearance distances between the coaxial cable and any exposed HV terminations are maintained.
5. Where cabling is to be routed around the hinge of the door it should be mechanically supported on both sides of the hinge and sufficient slack provided to enable the door to fully open. If possible, additional sleeving should be placed around the cables.
6. The cable length shall be secured to ensure no load is present on cables and excessive lengths of cabling shall be secured within the trunking.

**8**



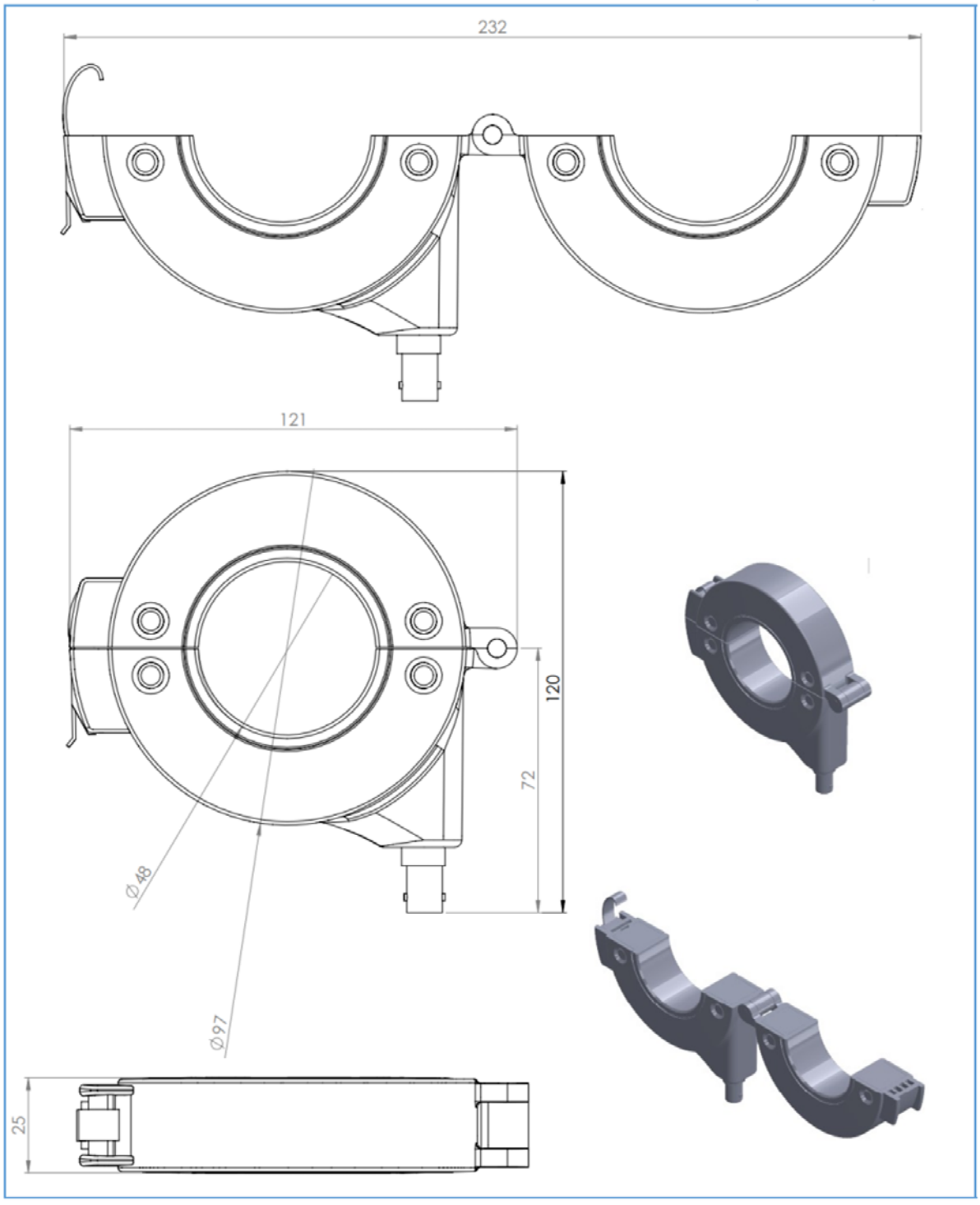
1. *If required mount the feed through bulk*head in a suitable location such that it does not infringe on the operation of the switchgear. Connect the chassis Earth to a suitable Earth point .
2. *Terminate the coaxial cable onto the rear of* the bulkhead or the monitoring system as required.
3. Ensure the screen of the coaxial cable is connected to Earth by using a modified coaxial cable with screen earth connection or ensure the feed through bulk head outer is Earthed.

**9**


1. Where possible inject a known PD source through the RFCT and ensure continuity of the wiring to the measurement device being used on site.
2. Replace all cable box covers.
3. Place a warning sticker similar to that shown above onto the outside of the cable box that clearly identifies that RFCT's have been permanently installed within the cable box.

# RFCT Quick Install Guide

## RFCT Dimensions (mm)



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