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Engineering Recommendation G102

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Pressure rise in enclosed substations

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PUBLISHING AND COPYRIGHT INFORMATION

Operations Directorate
Energy Networks Association
6th Floor, Dean Bradley House
52 Horseferry Rd
London
SW1P 2AF

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Foreword

This Engineering Recommendation (EREC) is published by the Energy Networks Association (ENA) and comes into effect from the date of publishing. It has been prepared under the authority of the ENA Engineering Policy and Standards Manager and has been approved for publication by the ENA Electricity Networks and Futures Group (ENFG). The approved abbreviated title of this first issue engineering document is “EREC G102”.

This EREC offers guidance on the recommended considerations when undertaking pressure rise risk assessments in substations

BS EN 61936-1, Sub-clause 7.5.2.1, states that a building design “shall take into account the expected mechanical loading and internal pressure caused by an arc fault”. This EREC assists with methods to demonstrate compliance to this requirement.

The guidance in this EREC captures learnings and findings from the following.

- EA Technology Module 4 (substations) Strategic Technology Programme reports.
- CIGRE activity.
- Previous experience in IEC Maintenance Team 14 during the development of BS EN 62271-200.

A basic pressure rise calculation model, based on the 2015 CIRED Paper 0739 [N1], is available from ENA in spreadsheet format, for informative use. The simple model calculation described in CIRED Paper 0739 [N1], suggests that the quick calculation method used, gives very similar results to the lengthy iterative process in the CIGRE Brochure 602 [N3]. At the time of publishing, the model has not been extensively tested, but early results are considered acceptable.

The term ”user” relates to any user of this document.

Where the term “shall” or “must” is used in this document it means the requirement is mandatory. The term “should” is used to express a recommendation. The term “may” is used to express permission.

Introduction

Internal arc rated HV switchgear that vents into a substation building could, in the unlikely event of failure, produce a pressure rise. Pressure rise in substations can occur following an arc flashover within the switchgear, leading to a pressure relief device to operate, and subsequent pressure build up within a substation. For the basis of calculating pressure rise in substations, most ENAMCs specify the methodology quoted in BRE TCR 20/97 [N2]. Where this test is not representative of the substation design, pressure rise calculations should be performed. However, it is difficult to calculate pressure rise within substations due to several reasons.

- There are numerous designs of substation buildings and switchroom types, with varying volumes.
- The electrical plant contained within substations varies according to manufacturer, type, age and configuration.
- Electrical faults may occur in a wide range of locations within the different types of equipment.
- Potential fault levels and circuit protection times vary according to the location of the equipment on the network and all may affect the level of a subsequent pressure wave in the event of a catastrophic failure.

A generic assessment can be used for substations of similar design (such as modern unit type distribution substations) located in similar environments. For most primary and grid substations, individual assessment of pressure rise is normally necessary.

There are a number of different methods to calculate pressure rise and the accuracy depends on the type of model used. CIGRE Brochure 602 [N3], provides guidance on the limiting factors of various models for calculating pressure rise.

There are three types of models that can be used for pressure rise calculation.

a) Basic – a basic calculation to quickly determine uniform pressure rise inside an arc compartment in typical MV and HV GIS applications.

b) Enhanced – uses a basic approach and adds known approximations. The limitations depend on the approximations used.

c) Computational fluid dynamic – calculates spatial pressure distribution and gas flow. For use in odd shaped geometry and large substations.

This EREC presents typical pressure levels in substations, recommended mitigation against pressure rise and also introduces a basic model concept to help determine pressure rise.

1 Scope

This EREC provides guidance for the assessment of pressure rise that can occur in enclosed substations following a switchgear related failure.

Pressure rise assessment is considered for the following instances/applications.

- Indoor 6.6 kV, 11 kV, 20 kV and 33 kV switchgear within indoor type substations.
- Design of new substations.
- Operational considerations for existing 6.6 kV, 11 kV, 20 kV and 33 kV switchgear.

Outdoor switchgear and pole mounted switchgear is not included in this EREC.

This EREC does not provide a detailed model of how to calculate pressure rise in particular types of substations, but does include guidance on a basic model and also the limitations of using pressure rise models.

2 Normative references

The following referenced documents, in whole or part, are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS EN 61936-1: *Power installations exceeding 1 kV a.c. Part 1: Common rules*

BS EN 62271-200: *HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

BS EN 62271-212: *Compact Equipment Assembly for Distribution Substation (CEADS)*

PD IEC/TR 61641: *ENCLOSED LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES – Guide for Testing Under Conditions of Arcing Due to Internal Fault*

Other publications

[N1] CIRED Paper 0739 2015, *Internal Arcs: Pressure Rise Versus Cooling Methods in Air Insulated MV Switchgear*

[N2] BRE TCR 20/97, *The development of a Synthetic Explosion Test for the Assessment of Electrical Substation Enclosures*

[N3] CIGRE, Working Group A3.24, Brochure 602*, Tools for the Simulation of the Effects of the Internal Arc in Transmission and Distribution Switchgear, 2014*

[N4] EA Technology, Strategic Technology Programme 4 (Substations) Report No. 6046 *Internal Arc Requirements of New LV and HV Switchgear,* 2007

[N5] EA Technology, Strategic Technology Programme 4 (Substations) Report No. 6302 *Review of Methods to Dissipate Pressure in Substations During Equipment Failure,* 2009

[N6] ENA TS 41-36, 2012 Issue 3, *Distribution Switchgear For Service Up To 36kV (Cable And Overhead Conductor Connected)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
arc fault current
arc current which flows across a given point of fault resulting from an insulation fault

3.2
basic model
mathematical approach for the calculation of pressure rise due to an internal arc using simplified equations under basic assumptions

3.3
CENELEC
European Committee for Electrotechnical Standardization

3.4
computational fluid dynamics
branch of fluid mechanics that uses numerical analysis and data structures to solve and analyse problems that involve fluid flows

NOTE: Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

3.5
enhanced model
mathematical approach for the calculation of pressure rise due to an internal arc

NOTE: Calculations are applied using a number of extensions to the basic model with respect to equations and assumptions.

3.6
ENAMC
member company of the Energy Networks Association

3.7
exhaust compartment
enclosed volume adjacent to the arc compartment which receives the arc exhaust

3.8
GIS
gas insulated switchgear