Assessing the condition and remaining life of underground electrical cables

energy institute

ASSESSING THE CONDITION AND REMAINING LIFE OF UNDERGROUND ELECTRICAL CABLES

First edition

December 2016

Published by
ENERGY INSTITUTE, LONDON
The Energy Institute is a professional membership body incorporated by Royal Charter 2003
Registered charity number 1097899

The Energy Institute (EI) is the chartered professional membership body for the energy industry, supporting over 23 000 individuals working in or studying energy and 250 energy companies worldwide. The EI provides learning and networking opportunities to support professional development, as well as professional recognition and technical and scientific knowledge resources on energy in all its forms and applications.

The EI's purpose is to develop and disseminate knowledge, skills and good practice towards a safe, secure and sustainable energy system. In fulfilling this mission, the EI addresses the depth and breadth of the energy sector, from fuels and fuels distribution to health and safety, sustainability and the environment. It also informs policy by providing a platform for debate and scientifically-sound information on energy issues.

The EI is licensed by:
- the Engineering Council to award Chartered, Incorporated and Engineering Technician status;
- the Science Council to award Chartered Scientist status, and
- the Society for the Environment to award Chartered Environmentalist status.

It also offers its own Chartered Energy Engineer, Chartered Petroleum Engineer and Chartered Energy Manager titles.

A registered charity, the EI serves society with independence, professionalism and a wealth of expertise in all energy matters.

This publication has been produced as a result of work carried out within the Technical Team of the EI, funded by the EI's Technical Partners. The EI's Technical Work Programme provides industry with cost-effective, value-adding knowledge on key current and future issues affecting those operating in the energy sector, both in the UK and internationally.

For further information, please visit **http://www.energyinst.org**

The EI gratefully acknowledges the financial contributions towards the scientific and technical programme from the following companies

BP Exploration Operating Co Ltd
BP Oil UK Ltd
Centrica
Chevron
CLH
ConocoPhillips Ltd
DCC Energy
DONG Energy
EDF Energy
ENGIE
ENI
E. ON UK
ExxonMobil International Ltd
Kuwait Petroleum International Ltd
Maersk Oil North Sea UK Limited
Nexen
Phillips 66
Qatar Petroleum
RWE npower
Saudi Aramco
Scottish Power
SGS
Shell UK Oil Products Limited
Shell U.K. Exploration and Production Ltd
SSE
Statkraft
Statoil
Talisman Sinopec Energy (UK) Ltd
Tesoro
Total E&P UK Limited
Total UK Limited
Tullow Oil
Valero
Vattenfall
Vitol
World Fuel Services

However, it should be noted that the above organisations have not all been directly involved in the development of this publication, nor do they necessarily endorse its content.

ISBN 978 0 85293 952 9

Published by the Energy Institute

Hard copy and electronic access to EI and IP publications is available via our website, **https://publishing.energyinst.org**.
Documents can be purchased online as downloadable pdfs or on an annual subscription for single users and companies.
For more information, contact the EI Publications Team.
e: **pubs@energyinst.org**

Contents

Contents continued **Page**

LIST OF FIGURES AND TABLES

FIGURES

Contents continued **Page**

TABLES

ACKNOWLEDGEMENTS

Assessing the condition and remaining life of underground electrical cables was produced by the EI Power Utility Committee (PUC), and authored by Bob Dean (Edif ERA). During this project, PUC members included:

Graham Beale	Engie
Alan Dickson	Scottish Power (Chair)
Steve Gilmore	Uniper
Phillip Horner	Centrica
Edward Jamieson	RWE
Stuart King	EI (Secretary)
Ali Kuba	Saudi Aramco
Chris Martin	Engie
Daniel Rawdin	SSE
Doug Smart	EDF Energy
Konstantinos Vatopoulos	Aramco Overseas

The EI also acknowledges the following individuals for contributing to the stakeholder review of this publication:

Paul Donnellan	Shell
Zaur Sadikhov	Shell

The EI wishes to acknowledge the following organisations for their contributions to this project in providing information and images:

BAUR Test Equipment
Elmeridge Cable Services
High Volt
HVPD
Megger
Omnisens
Redskye Technology
Wirescan

Technical editing was carried out by Stuart King (EI).

Affiliations are correct at the time of contribution.

FOREWORD

Electrical power cable condition assessment has changed in recent years. In the past, normal practice was to leave a cable undisturbed until an unacceptable number of failures occurred and then to replace the cable. Today there are a confusing number of cable condition assessment techniques and systems available. Many technical papers have been written on the subject, but they tend to cover a particular test method, and are often written by specialists working for test equipment manufacturers, naturally favouring their own company's test methods and equipment.

Assessing the condition and remaining life of underground electrical cables was commissioned by the Energy Institute (EI) Power Utility Committee (PUC), with the intention of providing practical independent guidance on assessing the condition and remaining life of underground electrical power cables.

Efforts have been made to avoid duplicating existing publications, and where useful publications exist, these have been referenced in the text.

This publication is primarily for engineers working in the energy generation industry, but it also provides a useful source of information for engineers in other industries as well as students, engineering managers and consultants.

As well as being read in whole, this publication can be used as a reference document where relevant sections are referred to as and when required, for example when considering a particular test or assessment method.

The information contained in this document is provided for general information purposes only. Whilst the EI and the contributors have applied reasonable care in developing this publication, no representations or warranties, expressed or implied, are made by the EI or any of the contributors concerning the applicability, suitability, accuracy or completeness of the information contained herein and the EI and the contributors accept no responsibility whatsoever for the use of this information. Neither the EI nor any of the contributors shall be liable in any way for any liability, loss, cost or damage incurred as a result of the receipt or use of the information contained herein.

The EI welcomes feedback on its publications. Feedback or suggested revisions should be submitted to:

Technical Department
Energy Institute
61 New Cavendish Street
London
W1G 7AR

1 INTRODUCTION

1.1 SCOPE

This publication describes the onsite methods used to test underground electrical cables rated above 1 000 V phase to phase with paper insulated, lead covered (PILC), crosslinked polyethylene (XLPE) and ethylene propylene rubber (EPR) insulation. The test methods are applicable to generation, power distribution, high voltage (HV) motor and HV industrial cable types used in generation plants. A section is also included on subsea export and array cables for offshore wind farms.

1.2 TARGET AUDIENCE

This publication is for:

- engineers carrying out onsite testing of underground electrical cables, and
- asset managers who may be instructing others to carry out such testing.

It also provides useful information for anyone wishing to understand the results of electrical cable testing and condition assessment reports.

As well as being read in whole, this publication can be used as a reference document where relevant sections are read as and when required. The first section covers cable degradation and failure modes – the reader should ensure they understand how a cable can degrade and fail before they consider the various test and diagnostic methods described in later sections.

1.3 HISTORICAL PERSPECTIVE AND CHANGES IN CABLE DESIGN

Electrical cables were first developed at the end of the nineteenth century and for many years the prevailing policy was to test the cable when first installed but not to carry out any further testing. Cables were repaired (with a short length of cable and two joints) when a fault occurred. They were replaced when the incidence of faults on the circuit became too high. Where testing was carried out on electrical cables the test method was either a DC voltage withstand test or a direct current (DC) insulation resistance (IR) measurement.

The traditional cable design was PILC. This could be screened or belted. The belted cable design has paper insulation applied over the three laid up cores to achieve the phase to earth insulation thickness (see Figure 1).