MEASUREMENT OF THERMOMECHANICAL PROPERTIES OF 400 kV 2500 mm² CABLE

James **PILGRIM,** Jack **HUNTER**, Neil **PALMER;** University of Southampton, Southampton, United Kingdom, jp2@ecs.soton.ac.uk, j.a.hunter@soton.ac.uk, nlp@ecs.soton.ac.uk

Brian **GREGORY**; Cable Consulting International ltd, Sevenoaks, United Kingdom, brian.gregory@cableconsulting.net

David **MOORHOUSE**, National Grid plc, Warwick, United Kingdom, david.moorhouse@nationalgrid.com

ABSTRACT

Knowledge of the thermomechanical properties of cable systems is vital in designing efficient cable support structures, which will be able to withstand the forces exerted by the cable system but with minimum cost. In order to better understand the forces produced by large 400kV cables with 2500mm² conductors, a series of laboratory tests have been commissioned. A bespoke test rig was constructed which is capable of measuring the axial, transverse and torsional stiffness of the cable, along with the force produced under constrained heating. This paper provides a summary of the tests conducted and the key results obtained.

KEYWORDS

Axial stiffness, transverse stiffness, torsional stiffness, thermal expansion, thermomechanical forces, XLPE Cable

INTRODUCTION

The need to achieve ever higher cable ratings on transmission circuits has led to the routine adoption of 2500mm² XLPE cable circuits across the 400kV transmission network in the UK. A critical element in the design of the overall cable system for such circuits is the provision of supporting steel work, for instance around tunnels and approaching sealing ends in substations. An engineering requirement exists for these structures to withstand the forces exerted on them by the cable, while at the same time being cost effective. In order to achieve a suitable compromise between the cost of the overall system and its mechanical integrity over the life of the cable asset, a good understanding of the thermo-mechanical response of the system is vital.

While thermomechanical forces (TMF) have always been accounted for in the design of the cable support structures, many of the design assumptions used had been based on the properties of oil-filled paper insulated systems [1]. Given the widespread use of 400kV XLPE insulated cables within the UK, National Grid sought to revise its technical guidance on thermomechanical forces to account for the potential differences in behaviour between polymeric and oil-filled cables. To enable this, a series of tests were commissioned on 400kV XLPE insulated cable samples to enable a comparison of their performance with conventional UK design assumptions relating to TMF.

This paper describes the construction of the test rig, including useful lessons learned which might be of benefit to others carrying out similar tests. Results of the different tests are compared, with relevant features specific to the particular cable type discussed.

CABLE SPECIFICATION

The cable sample tested is typical of several recent installations within the 400kV network in the UK. The key dimensions are summarized in Table 1. The cable has a 2500mm² Milliken conductor and a continuously welded smooth aluminium sheath.

Table 1 – Cable Dimensions

Component	Material	Outer Diameter
Conductor	Copper	65.0 mm
Conductor Screen	Semiconducting polymer	69.5 mm
Insulation	Cross linked polyethylene	123.5 mm
Insulation Screen	Semiconducting polymer	126.5 mm
Binder	Polymeric	129 mm
Sheath	Aluminium	132 mm
Serving	Polyethylene	144 mm

TEST RIG DESIGN PRINCIPLES

In order to make best use of the laboratory space available, it was not considered possible to develop separate test rigs for the different tests to be undertaken as had been the policy in previous work [2]. For this reason, a common frame design was identified which would enable samples of approximately 5.5m in length to be tested for axial, transverse and torsional stiffness. Although each test type required additional accessories to be bolted on to the rig, this appeared to offer a sensible compromise.

The main frame of the rig consists of a tubular steel frame, as shown in Fig. 1. The tubes are intentionally hollow, allowing cooling water to be passed through the frame during the long term tests. This is a necessary given the use of ac current to control the temperature of the cable sample during tests, meaning that some induced currents were found in the frame. As will be shown by the axial test results, a rig temperature variation as small as 2°C is significant.