220 kV Transpower NZ North Auckland and Northland (NAaN) Project - Design Validation of Thermo-mechanical Behaviour

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ABSTRACT

This paper is based on work that was motivated by the challenges associated with the installation of some 18 km of new 220 kV underground cable circuits between Albany & Hobson Substations in Auckland New Zealand. The paper describes the evaluation of the performance of the joint restraint system and that of the dilatation mechanism that was designed to cope with the relative movement caused by thermal expansion as well as seismic motion. Issues relating to the effects of traffic-induced bridge vibration on the dilatation span are also discussed.

KEYWORDS

Thermal expansion, joint force, dilatation span, clamp force, vibration, resonance, damping.

INTRODUCTION

The supply and commissioning of approximately 18 km (route length) of new 220 kV underground cable circuits between Albany & Hobson Substations in Auckland New Zealand involved:

- The design, manufacture & installation of 220 kV 2,500mm² & 1,600mm² copper-enamelled (CuE) cables & accessories.
- The establishment of the thermo-mechanical characteristics of the cables.
- The design & verification of the snaking arrangement designed to restrain the cables before entering the joint bay and the evaluation of forces imposed onto the joints by longitudinal thermal expansion of the cables.
- The design of special clamping arrangement in the joint bays and substation basements.
- The design & verification of the cable installation arrangement / support structure on the 1.4 km long Auckland Harbour Bridge (AHB) to cater for both horizontal and vertical bridge movements, which included design of the dilatation mechanism at the expansion joints and verification of the mechanical behaviour of cable when subjected to simulated thermo-mechanical and seismic movement, and bridge vibration.
- The installation of the 220kV cables & associated optical fibre cables in a single pull without joints on the constantly vibrating bridge structure.

The paper focuses on the experimental evaluation of the performance of the joint restraint system and the ability of the joint to withstand longitudinal forces imposed onto it by thermal expansion of the cable. The paper also describes the performance of the dilatation mechanism that was designed to cope with the relative movement caused by thermal expansion. The dilatation mechanism was also designed to accommodate bridge motion due to seismic activity. Issues relating to traffic-induced bridge vibration on the dilatation span are also discussed.

Full-size prototypes of the cable restraining systems for joints were commissioned to verify the level of transmitted longitudinal force to the joint due to thermal expansion. The effectiveness of the joint restraint systems was established as a function of time and applied force. A full-size prototype of the dilatation structure was commissioned to include a computer-controlled hydraulic actuator to mimic the relative (longitudinal) motion between the bridge and the cables due to thermal expansion and seismic activity. The restraining forces were experimentally established and cyclic endurance tests that simulated some 80 years' daily expansion / contraction as well as seismic motion was undertaken. The effect of the cyclic loads on the cable was evaluated by monitoring cable curvature and longitudinal force. Cable curvature, which was measured optically, was used to predict strain in the aluminium sheath which was used as the primary design limit for establish cable path. The vibration characteristics (namely resonant frequencies and self-damping) of the prototype dilatation span were established and the ambient vibration characteristics of the bridge were monitored to determine if resonance was likely to occur and if additional damping was required to minimize the possibility of fatigue failure of the cable. Finally, the vibratory response of the dilatation span in-situ was monitored for three months to confirm that additional damping was not necessary. The content of this paper is a summary of three reports issued by Victoria University [1][2][3] and two reports issued by Nexans Olex [4][5].

JOINTBAY CABLE RESTRAINT

This section describes a series of experiments undertaken to establish the behaviour of the prototype installation aimed at experimentally establishing the forces imposed onto the cable joints by thermal expansion of the cable. Longitudinal forces were applied to the conductor at one extremity of the installation and the reaction force transmitted through the snaking arrangement as well as the displacement experienced by the conductor at the other extremity was measured.

The test rig comprised a length of cable set in a snaking arrangement mounted on a solid concrete slab using cable clamps and specially-designed steel supports. The entire central section of the assembly was then encased in Fluidised Thermal Backfill as shown in Figure 1. At one extremity of the test rig, a hydraulic actuator, fitted with a load cell, was used to apply pre-determined forces to the conductor along its longitudinal axis. At the other extremity, a second load cell, mounted onto a rigid and firmly-secured frame, was used to measure any reaction force and displacement produced by the conductor. A pressure-control valve was used to set and maintain (for one hour each) the applied forces (tension followed by force and displacement produced by the conductor.