Low-voltage cable systems: aluminium conductor corrosion and online monitoring

Armand **VAN DEURSEN**, Peter **WOUTERS**; Eindhoven University of Technology, the Netherlands, a.v.deursen@tue.nl, p.a.a.f.wouters@tue.nl,

Peter **VAN DER WIELEN**, Fred **STEENNIS**; Eindhoven University of Technology & DNV GL, the Netherlands, p.c.j.m.v.d.wielen@tue.nl, fred.steennis@dnvgl.com

ABSTRACT

The role of the low-voltage grid is changing from being just the final step in the power supply chain to facilitator of renewable energy generation on residential level. Therefore, its importance is steadily increasing in terms of grid reliability. Parts of the low-voltage grid, however, are ageing. These developments increase the need of distribution system operators to further find economically feasible ways to monitor and diagnose their low-voltage assets. Firstly, this paper looks into degradation mechanisms, in particular corrosion of aluminium conductors, a phenomenon that may, for instance, occur in case a damage is inflicted to a cable without directly causing a loss of connection. Secondly, the presence of high peak currents with short duration are being measured in the field. The research aims to create better understanding of the relation between the occurrence of peak currents and subsequent failures in the connection.

KEYWORDS

Aluminium, corrosion, dry-band arcing, electric breakdown, fault currents, power cable insulation, power system monitoring, conductors.

INTRODUCTION

The low-voltage (LV) distribution grid is currently being used in a different way than it was originally designed for. When the LV grid was installed, the connections made from this grid were to customers which solely consumed electrical energy. The load cycling was rather predictable and conductor cross sections were dimensioned based on relatively constant coincidence factors. Customers now use the grid as storage for their excess energy produced by the photovoltaic (PV) system on their rooftops, causing bidirectional current flows. They also use the grid as energy carrier to charge their electric vehicles. This leads to highly fluctuating load cycles, especially if multiple customers, connected to the same distribution connection, choose to charge their cars simultaneously. In addition, the heat demand from customers is now also increasingly electrified due to e.g. heat pumps becoming more popular. The trend in these modern developments is expected to continue in the foreseeable future.

The use of sustainable technologies may be commendable in itself with respect to the energy transition. It does, however, lead to a higher dependence on the supply of electricity and an outage in the future will have a larger impact on society than it had in the past. Therefore, the importance of the low-voltage grid reliability is increasing. Another interesting perspective is from the economical perception. Data from one of the Dutch Distribution System Operators (DSOs) (with 2.7 million connections) over 2015 show that the repair costs for the LV grid are nearly three times the amount spent on repairs in the medium-voltage (MV) grid, see Table 1 [1].

Table 1
Repair costs and Customer Minutes Lost (CML) for the LV and MV networks of a single grid operator in 2015.

Grid voltage levels	MV	LV
Estimated cost per outage	€ 7,000	€ 2,300
Number of outages per year	627	5,500
Average CML per outage	38,000	2,500
Total costs per year	**M€ 4.4**	**M€ 12.7**

For aforementioned reasons, DSOs are interested in gaining better understanding on what causes degradation of their LV grid components. They are also interested in developing methods to monitor their LV networks and assess their quality. Because of the large number of LV connections, any solution would have to be cheap and preferably aggregating a large number of customers in order to be affordable.

This paper discusses two degradation mechanisms, being corrosion of aluminium conductors and dry-band arcing inside LV cables. Both can occur when water is able to penetrate to the conductors. Corrosion requires a constant exposure to moisture and an available current path through this moisture. Parameters that influence the process are studied in this work. Dry-band arcing requires periodical exposure to moisture and leads to intermittent peak current, as was previously shown in laboratory experiments [2]. Two different measurement systems were assembled and placed in the field, where they now record similar current and voltage waveforms to those recorded in the laboratory. Some, in our opinion interesting, results are discussed and recommendations are formulated for potential future large scale implementation.

Since degradation mechanisms can depend on different electrical parameters and local soil properties, the presented work is oriented to the specific situation in the Netherlands, which will be discussed in the following section.

SITUATION IN THE NETHERLANDS

In the Netherlands, nearly all low-voltage power distribution is realized through underground power cables. These cables have four conductors and an earth screen. The cables are buried at a depth of about 60 cm. Because 65% of the Netherlands lies below sea level, these cables usually are exposed to a wet environment. The three phases are operated at a line-to-line voltage of 380 V (± 10%), resulting in a 230 V phase-neutral voltage. The power frequency is 50 Hz.