A TE Connectivity Rail white paper

MATERIAL AND COMPONENT SELECTION

is crucial to high-voltage success

How TE Connectivity works in partnership with customers to deliver technical solutions that extend beyond our own product ranges.


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AS A TECHNOLOGY LEADER, TE CONNECTIVITY DESIGNS AND MANUFACTURES THE ELECTRONIC AND ELECTRICAL CONNECTORS, COMPONENTS AND SYSTEMS INSIDE PRODUCTS THAT ARE CHANGING THE WORLD, MAKING THEM SMARTER, SAFER, GREENER AND BETTER CONNECTED.

In the world of rail, and rolling stock applications in particular, TE Connectivity delivers the broadest portfolio and systems expertise required to connect power and data systems safely and reliably, that portfolio including products ranging from high voltage 'roofline' components and systems to the low voltage cabling and connector systems installed throughout the entire train.

In this white paper, High Voltage Development Engineering Manager, Elizabeth da Silva, describes how TE Connectivity works in partnership with its customers to help them understand the implications of material and component selection in 25 kV roofline systems. This collaborative approach helps customers make design decisions that will minimise the potential risk of failure in 25 kV roofline systems and ultimately deliver a reliable rail network.

Contents

CONNECTING TRAINS TO POWER SUPPLIES

Electric trains rely on high-voltage roofline systems that provide the electrical connection between the overhead catenary wires and the transformers that supply the power for traction and other on-board loads.

Roofline systems typically include major components such as switchgear, insulators, intercar cables, surge arrestors, bushings and downleads. Each of these major components has a vital and specialist role and train builders and operating companies turn to experts like TE Connectivity to supply them as they understand the reputational, political and financial costs of power failure.

But roofline systems also rely on smaller components such as lengths of solid conductor busbar or flexible braids that transfer power between the major components, the support structures and the nuts and bolts that hold connections in place.

These simple connectors and structures play as important a role as the high value components, but one that is less obvious and if their selection is not considered carefully, they can introduce the risk of failure.

UNIQUE OPERATING CONDITIONS

Train roofline systems are subject to conditions experienced by few high-voltage components in the utility industry. The operating environment includes exposure to pollution, humidity, airborne sea salt, high speed air flow, rapid air pressure and temperature changes, driven rain and, in some cases, high altitude operation. The electrical systems also experience mechanical shock and vibration of train travel and wide variations in supply voltages.

Every railway line is unique and the key to a reliable power system is in recognising the operating environment and the impact that it will have on components throughout their life.

FLASHOVER AND ITS CAUSES

A major source of failure in high-voltage roofline systems is through electrical flashover. This is the term that describes the short circuit when the current jumps from the electrical conductor to the roof of the train. It is the passage of electric current through the air gap between live components and the body of the train.

The immediate result is loss of the power supply and deceleration, followed by the train switching over to battery power, with the batteries typically providing sufficient standby power to support critical systems, such as lighting, door opening and communications.

Some incidents will cause a relatively short-lived interruption to service but should a failure occur on a major component, it can have a domino effect on the day’s timetable and the availability of the train affected.

Also known as arc flash, flashover can occur anywhere in the world but certain conditions make it more likely. These are built up from a number of factors, including the environment influencing the insulating quality of air, the design of components in the vicinity of charged components, including the layout and the quality of the materials used in those components.

ELECTRIC FIELD STRENGTH

Flashover takes place when the electric field around high voltage conductors measured in kilovolts per millimetre (kV/mm) becomes so strong that it overcomes the insulating limits of air.

Even the untrained observer is familiar with the low buzz that arises from strong electric fields at substations and on overhead lines. This buzz grows louder on structures that have been exposed to high levels of pollution and in the dark a blue glow is even visible. The same phenomenon can happen on the high voltage roofline system of a train.

Such systems are reliant on the air surrounding the high voltage components insulating against flashover Distances between the live components and the train structure, called clearance and creepage, define the final withstand of the system.

But pollution, humidity, air pressure and temperature and even the shape and material of components can all impact electric field strength, meaning that the clearance and creepage length must be increased for some specific applications.

THE IMPACT OF GOOD DESIGN

Electric field strength can be minimised by good design of the components that form part of a high-voltage system so that they have smooth, rounded shapes without sharp points or textures.

The physical shape of charged objects impact the shape and strength of an electric field. Invisible to the naked eye, ionised particles travel between surfaces in an electric field at right angles to the surfaces. For a smooth curved surface, the electric field will be able to spread out evenly.

But a pointed surface will cause the charged particles to concentrate around it, increasing electric field stress and, consequently, increasing risk of flashover.

Electrical clearances can be severely comprised by water flow (waterfall effect) under conditions of high rainfall and when the train is stationary or moving slowly; thus the effect of equipment geometries on water dispersal can be an important consideration for systems destined for operation in wetter climates.

QUALITY OF MATERIALS

Another aspect to consider is the quality of the materials used in roofline systems. Many smaller connectors such as nuts, bolts, brackets and braided connectors may have been specified to achieve the lowest price and this could leave these connectors vulnerable to corrosion, which will in turn spread contamination over insulator surfaces, reducing their performance.

Even a simple copper braid can lead to issues. Inconsistencies in the tightness of the windings can mean loose strands, introducing areas where the electric field is highly concentrated and therefore more likely to fail.

Plus, poorly specified nuts and bolts can damage high value copper connectors through galvanic corrosion. While brass should be the first material that is connected to copper conductors, TE Connectivity has found some instances where low grade steel has been used and which has subsequently oxidised, contaminating the copper surface and calling for a replacement copper conductor.

AIR QUALITY AND POLLUTANTS

Humidity, pollutants and airborne salt can all have a major impact on the ability of air to insulate as they affect the dielectric strength of air.

And as altitude increases and air pressure drops, the wider gaps between air molecules allow electrons greater freedom to pass between particles, therefore reducing the voltage at which flashover will occur. This can be predicted using Paschen's law, which predicts the minimum gap needed to insulate a particular voltage at different pressures.

MECHANICAL REQUIREMENTS

Mechanical considerations also apply to the high voltage roofline system, for example concerning the operation of High Voltage Jumper Cables that provide electrical connection across the gap between train cars. Those cables may be subjected to continuous mechanical flexing in three axes due to the relative movements of adjacent train cars.

These movements inevitably lead to mechanical wear, which in turn could affect current carrying and high voltage withstand electrical performance.

Although the electrical and mechanical properties of such jumper cables can be well characterised as a component, system interactions need to be considered also. For example such components impose cyclic mechanical loads on the equipment they are connected to (typically insulator brackets and/or HV cable terminations), and their electrical impedance characteristics may influence the electrical interaction of the system.

REAL-LIFE PROCUREMENT

TE Connectivity can supply all the major and minor components of a high voltage roofline system, ensuring that every component is specified, designed and manufactured for an individual railway line and its operating conditions. But in reality, many customers order only the highly engineered components from TE Connectivity or other specialist suppliers and turn to other suppliers for the lower value connectors.

Typical components are the connectors such as the copper braids that link the major components, the brackets that hold them in place and all the way down to the nuts and bolts that hold the elements of the system together.

The design of components, the quality of the raw materials used to make them and variations introduced during manufacturing can all impact creepage distances and lead to a system that is only as strong as its weakest part.

And although these components may be seem to offer good value, if they are not specified with adequate care, they may introduce vulnerabilities through shortcomings in their design or quality.

When faced with a harsh operating environment, the roofline system as a whole will only be as strong as its weakest component. Through engineering analyses of systems that have experienced failure, TE Connectivity has found that although there can be many contributing factors the ultimate source of failure is often poorly specified low value connectors.

DESIGN CONSULTANCY

The rapid growth of urban, suburban and long distance 'high speed' electrified rail systems around the world has led to new challenges concerning environmental conditions of electrified rail operation.

Train designers also have to contend with market demands for improved energy efficiency (requiring reduced equipment weight and aerodynamic drag) and increasing the utilisation of space within the train 'envelope' for optimising passenger comfort and carrying capacity (resulting in reduced space HV roofline equipment).

These trends bring various factors and variables into play that can affect the performance and reliability of the train high voltage roofline system and associated equipment, but where long and trouble free operation has to be maintained and assured.

To meet these demands, TE Connectivity offers to work with its customers to evaluate the performance of roofline systems as a whole, performing technical analyses that includes physical inspection, environmental analysis, and review of operational and maintenance procedures.

At component interaction level expert TE Connectivity engineers can carry out finite element analysis using the physical structure of the 25 kV system to gain an understanding of the behaviour of the electrical and mechanical stresses when the system is live in order to identify the weak points.

This service helps train designers to optimise equipment selection and layout for performance and reliability, whilst ensuring minimal maintenance overhead for train operators/maintainers.

WORKING IN PARTNERSHIP

By being more than just a supplier of components and working closely in collaboration with its customers' engineering teams, TE Connectivity builds trust as a partner rather than a simple supplier.

As a provider of technical solutions, many rail operators and manufacturers turn to TE Connectivity to evaluate the reasons for failure on high-voltage roofline systems and recommend specifications for components that are outside the normal scope of its supply.

In an industry where every failure is important, the objective is to work with rail operators and train builders to improve performance, reliability and safety.

ABOUT THE AUTHOR

Elizabeth Da Silva Domingues is TE Connectivity's High Voltage Development Engineering Manager, and is responsible for high voltage roofline systems. She holds a doctorate in electrical and electronic engineering from the University of Manchester and is a Senior Member of the Institute of Electrical and Electronics Engineers. Originally from Caracas, Venezuela, has led multiple research projects in medium and high voltage systems within academia, government and industry and has also worked as a consultant for utilities, oil companies and manufacturing industries. She had published more than 50 technical papers on HV insulation in journals and conferences.

HISTORY OF TE CONNECTIVITY

TE Connectivity is a technology leader that designs and manufactures the electronic connectors, components and systems inside the products that are changing the world – making them smarter, safer, greener and more connected.

It is a leading supplier of high-voltage components to the rail industry that deliver proven longevity and performance in diverse and harsh environments. TE Connectivity's unique knowledge of materials science positions it at the forefront in developing the insulation materials that perform the essential task of insulating line power from the train structure.

Its legacy dates back to the 1950s when Raychem, which has since joined the TE Connectivity group, first used the technique of radiation chemistry to develop products. Since then, the firm has undergone a number of changes of name and structure. These include the name of Tyco Electronics, which the firm bore until March 2011 when it took the name TE Connectivity to reflect its role as a component and communications manufacturer.

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