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ICEC 2016

International Conference on Electrical Contacts

Du 6 au 9 Juin 2016
Edinburgh

Technical Areas and Topics

→Basic Phenomena and Fundamentals

→Contact Materials

→Power Contacts

→Sliding Contacts

→Connectors

→Reliability

→Degradation Mechanisms

→Arc Interruption

→Switching Behaviour

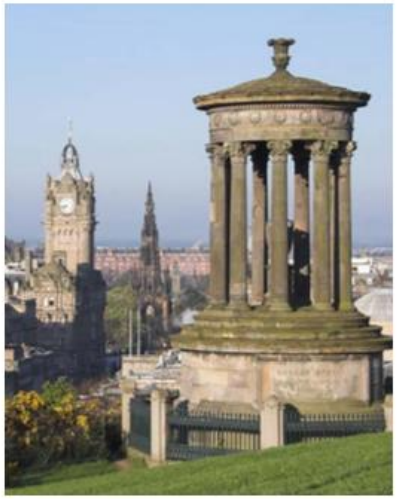
→Design and Function

→Modelling and Simulation

→New Technologies

→Specialist Applications (Automotive, Aerospace, Medical, Power Engineering)

The International Conference on Electric Contacts is a biennial event hosted by countries around the world. The venue for the Conference in 2016 is in the heart of Edinburgh, UK. The Conference typically attracts >200 delegates from a wide range of electrical/electronic industries as well as research establishments and universities. It provides a forum for the presentation and discussion of the latest research and development in the field of electric contacts from the nano scale to high power.



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The 28th International Conference on Electric Contacts

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Special thanks to
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Sessions

Fundamentals	0/4
Arcing Contacts I	6/6
Connectors I	1/6
Arcings Contacts II	4/4
Poster	9/16
MEMS ans Nano/Micro Contacts	0/5
Contact Materials	1/5
Slinding Contacts	2/5
Connectors II	0/5
Arcing Contacts	4/4
Modelling	3/4
Arcing Contacts III	3/4
Connectors III	1/4
Applications and New Technology	0/3
Arci,g Contacts IV	4/4

38/69

3.4

Mathematical model of the arc erosion in bimetallic electrical contacts

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Abstract-The mathematical model describing the non-stationary temperature field in a bimetallic contact consisting of a basic material and a covering is presented. It is based on the axially symmetric heat equation with the boundary conditions including an arc heat flux entering the covering surface and the ideal heat contact on the interface between covering and the basic material. The arc heat flux consists of the several components relating to the heating due to the electron and ion bombardment, arc radiation, inverse electrons, and cooling due to the electron emission, melting and evaporation. The dynamics of all these components is calculated for the brass contacts with the $AgCdO$ covering. It is found that the transition from the metallic arc phase to the gaseous arc phase occurs due to dynamical redistribution of the arc heat components. The resulting temperature fields in the basic contact and the covering enable us to choose the parameters for the optimal thickness of covering.

Keywords - electrical contacts; surface coating; arc erosion; mathematical model

5.1

Impact of the contact material on the extinction process of low voltage DC arcs

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Abstract—One major challenge of the recently upcoming DC networks is the switching off process. Switching off a circuit means to bring the flowing current steadily down to zero. The switching element of classical mechanical switchgear is an electric arc. By special measures within the switchgear the arc's conductance is lowered until the arc is extinguished. This paper illustrates the dependency of the maximum rate of decrease of the arc's conductance on the contact material. Three approaches are presented to analyze the arc's dynamic behavior and compared with each other. The obtained results of the different contact materials are discussed.

Keywords—contact material; electric arc; DC; dynamic behavior; thermal inertia; time constant; switching off process

5.1

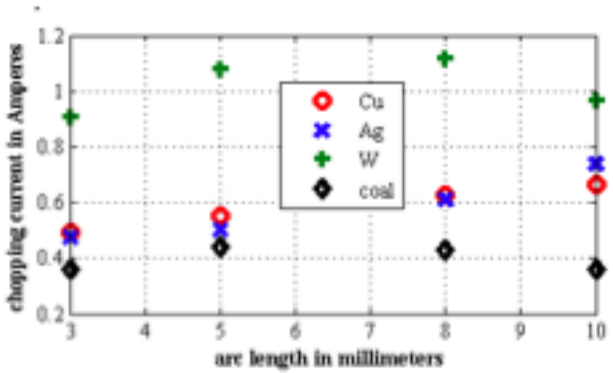

Fig. 10. Mean values of arc chopping currents/minimal arc currents

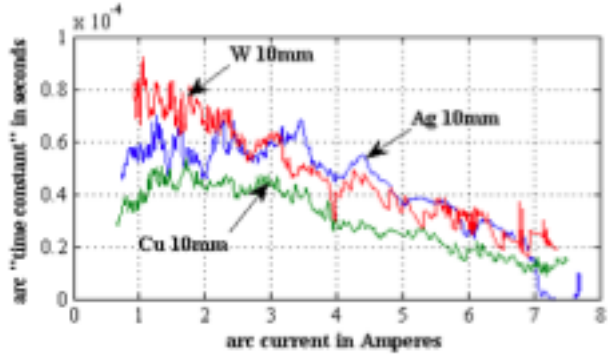

Fig. 15. Exemplary courses of the mean arc "time constants" of the analyzed metal electrodes at 10mm arc length

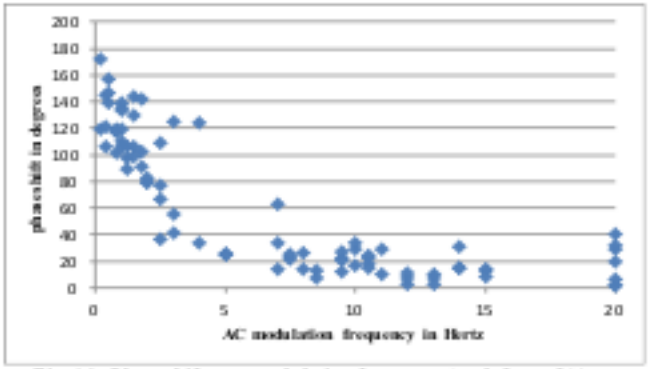

Fig. 16. Phase shift over modulation frequency (coal, 5mm, 5A)

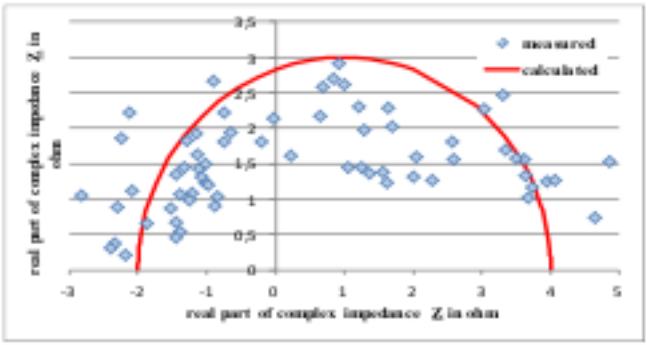

Fig. 17. Measurement-based and fitted impedance spectrum (Cu, 5 mm, 5A); frequency range: 1 Hz ... 150 kHz

5.3

Breaking performance of a dc contatcor for high-voltage dc on-board powersystems

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Abstract — Fundamental changes in energy supply have raised an increasing demand of DC technology for example in electric vehicles. These systems operate in a voltage range up to several hundred volts and nominal currents of several hundred amperes. Lithium-ion batteries are used as energy sources in these systems, which are capable of generating fault currents of several kiloamperes. The electrical requirements for switching devices in these systems are technically challenging. As a consequence of the demand for high performance powertrains, detailed investigations are necessary to cope with more powerful lithium-ion batteries and rising system voltages.

In the current study an arcing chamber with a double contact configuration has been designed for the application in an automotive powertrain for a system voltage of 450 V. The chamber is equipped with splitter plates. The breaking behavior of the arcing chamber has been investigated for prospective currents up to 2000 A as well as different time constants up to 3 ms. Different arcing chambers and their influence on the arc have been tested. Furthermore, different designs of the arcing chamber and the effect on the arc movement and quenching behavior have been investigated.

Keywords—switchgear, direct current, dc, arc splitter blades, high-voltage; automotive power train, on-board power systems

6.2

Experimental investigations on plasma pressure in a narrow gap for short time currents

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The experimental research shows the pressure of a short-time plasma in a narrow gap with two outlet ducts. The plasma pressure is recorded by a piezoelectric sensor with a resonant frequency of 500 kHz and a pressure range of 689 bar. Three different total cross sections of the outlet ducts of 2 mm², 4 mm² and 8 mm² are tested by applying a surge current formed as an 8/20 µs impulse with amplitudes of 5 kA, 11 kA and 23 kA. The recorded plasma pressure shows the behaviour during the impulse and the comparison of the different recorded plasma pressures yields the influence of the different current amplitudes and outlet ducts. The knowledge about the behaviour and the influences of different geometries gives a first indication of possibilities to control the plasma pressure.

Keywords—surge current; plasma pressure; spark gap; lightning protection

6.2

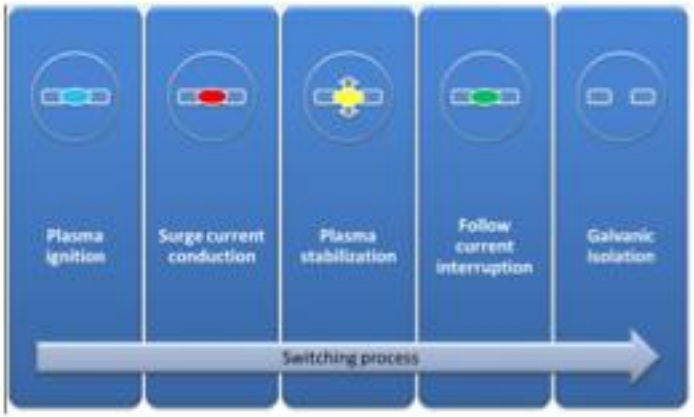

Fig. 1. Switching process for a surge protective device based on spark gap technology [3].

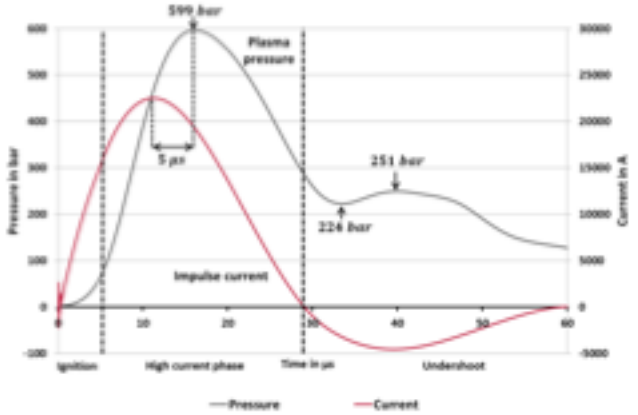

Fig. 6. Impulse current and plasma pressure at a total cross section of the outlet ducts of 2 mm and current amplitude of 23 kA.

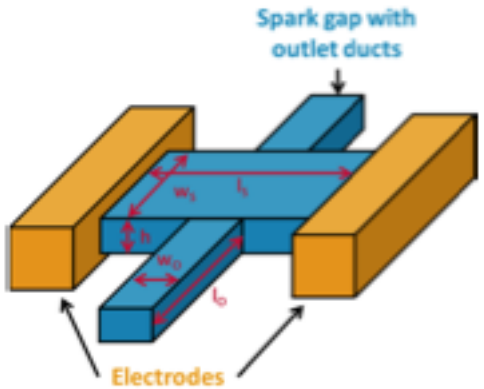

Fig. 3. 3-D model of the spark gap and electrodes without chamber walls and surface discharge device.

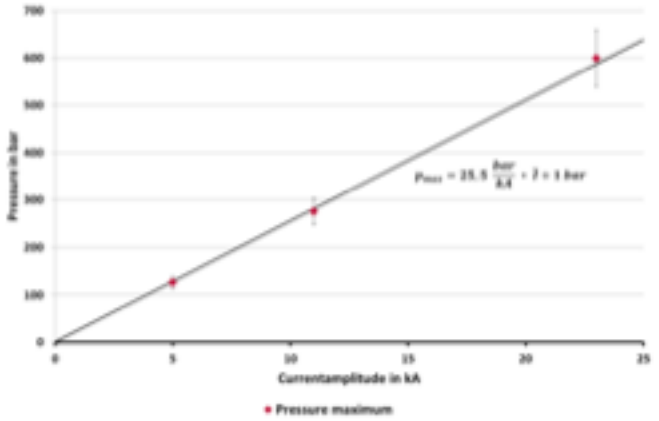

Fig. 8. Pressure maximum over the current amplitudes at a total cross section of 2 mm the outlet ducts.

6.9

A new software-based control unit for fault detection and isolation in LV DC systems

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***Abstract*— More loads in data centers, households, electric vehicles, and board networks are supplied by DC power. Therefore, different challenges in DC systems are need to be faced. As the DC system voltage increases, efficient and cost effective DC circuit breakers with high switching capacity are required. Hence, the development of reliable intelligent DC switching components and protection concepts is becoming increasingly important. In this research project a software-based control unit with distributed switches for low-voltage DC systems has been developed. The protection concept is based on the measurement of current through the switches and voltage across them, using current and voltage sensors. A fault detection and allocation algorithm has been proposed and implemented in LabVIEW platform. As a result, the control unit can specify the most suitable switching decisions. Different fault locations and types have been tested in the laboratory. The fault detection time and fault isolation time have been tested in an experimental 24 V DC test setup with a specific network topology which has been established in the laboratory. Hence, the functionality of the control unit has been verified.**

Keywords*— *Smart Modular Switchgear; DC systems; protection coordination; intelligent switching

6.10

A study of the Motion of High Current Arcs in Splitter Plates using an Arc Imaging System

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Abstract— **Arc modelling is a valuable tool in the evaluation of the switching performance of low-voltage switching devices (LVSDs) prior to testing real products. All modelling process requires a validation of the results against experimental studies. In this study an arc imaging system is used to investigate the arcing phenomena in splitter plates. The imaging system is applied to a flexible test apparatus which allows the control of important feature of a typical LVSD. The results show the formation of the arc into the plates and the separation of the arc as a restrike occurs in the main arc chamber. The phenomena results in a rapid reduction in the arc voltage before the arc re-enters the plates.**

Keywords-component; Arc Imaging, Splitter Plates.

6.10

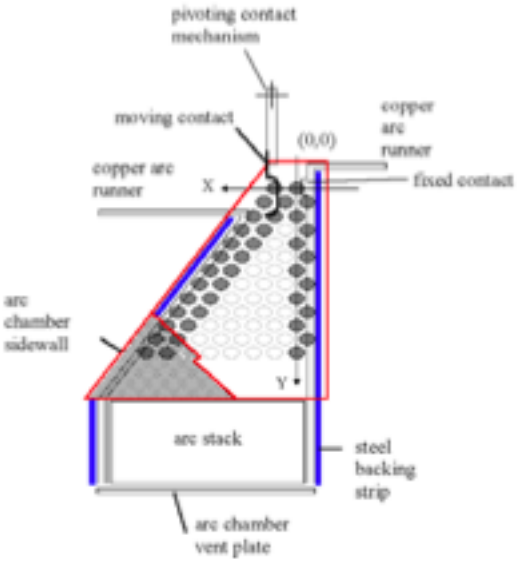


Fig.3 Schematic of the arc chamber of the FTA showing the moving contact and with optical fiber positions using in previous studies. Grey fibre were used to plot arc root postion. [6,7]

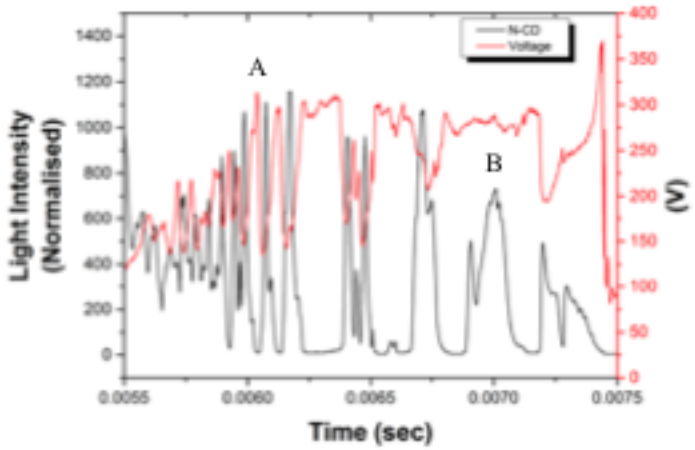
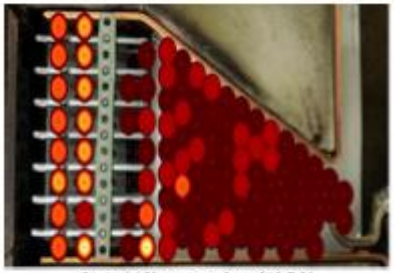
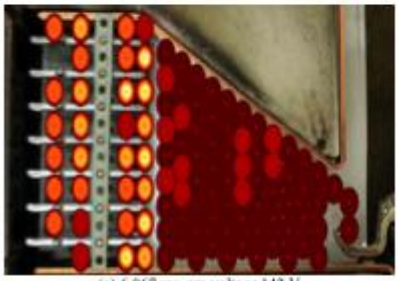


Fig.9 The Arc Voltage and Current and Light intensity on fibre CD for 300V supply voltage zoomed in to show interaction of arc voltage and splitter plates.

(a) At 6.047 ms with arc voltage 288.6 V.



(b) At 6.052 ms arc voltage 313.7 V.



(c) 6.067 ms, arc voltage 142 V

Fig. 10. events around point A in Fig 9. (mode 1, 5,15,30,50,70,80,90%)

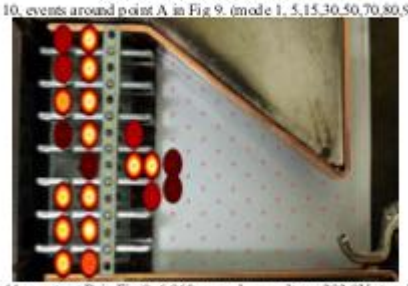


Fig. 11 events at B in Fig 9, 6.960 ms and arc voltage 283.9V. (mode 1, 3,10,20,30,40,50,60%)

11.1

Accelerated Degradation Testing for Aerospace Electromagnetic Relay in Long-Term Stockpile

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***Abstract*—It is difficult to obtain the failure data of high-reliability and long-lifetime aerospace electromagnetic relay, even if based on the traditional accelerated storage life testing method. Aiming at this issue Based on the reliability test technique, the scheme of accelerated degradation testing for aerospace relay was designed. The test system of aerospace electromagnetic relay storage parameters under temperature-accelerated stress was designed and developed. Taking a certain aerospace electromagnetic relay as the research object, the accelerated storage degradation testing (ASDT) was carried out. The most past research on storage reliability of relay only focuses on the measurement of relay contact resistance. And, the relay time parameters (closing time, opening time, overtravel time, rebound duration time.) which reflect main performance function was not monitored. So, in this paper the relay time parameters and relay contact resistance were detected simultaneously. The test system of relay storage parameters could be implemented the function that the contact resistances and time parameters of 40 aerospace relays under several temperatures were monitored automatically at the same time. And, the test system transmitted the test data to the host computer for processing. According to the analysis on experiment results of contact resistance, relay time parameters, the degradation phenomena and degradation mechanism of aerospace electromagnetic relay in long-term storage are investigated. These studies provide the basis and reference for latter aerospace electromagnetic relay storage life prediction and using the method of prognostics and health management.**

Keywords- storage reliability; accelerated degradation testing; electromagnetic relay; contact resistance; time parameters;

11.2

Influences of Contact Opening Speeds and Magnetic Fields on Break Arc Behaviors of $AgSnO_2$ Contact Pairs in DC Load Circuits

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Abstract—Both increases in contact opening speeds and application of external magnetic field are believed to be effective for realizing reductions in break arc durations. In this paper, $AgSnO_2$ contact pairs were operated in a DC inductive circuit (L=10mH) with 1 to 20 A at 14V under different contact opening speeds of 1mm/s and 200mm/s and with or without magnetic field application of 100mT, and break arc durations were measured. As a result, both increased contact opening speed and applied external magnetic field surely caused certain shortenings of break arcs. However, each of them seems to exhibit different influences on metallic phases and gaseous phases, respectively.

Keywords—contact opening speed; magnetic field; break arc; $AgSnO_2$; metallic phase; gaseous phase

Electric Circuit with Passive Elements for Suppressing Arc Ignition in DC Contacts

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Abstract— **The authors have studied the melting phenomena of breaking electric contacts. When the last stage of contacting current shuts down, a micro seconds order delay of the rising contact voltage from the melting contact voltage *Um* to arc voltage *Va* is able to intercept arc ignition. This paper proposes an improved circuit of only passive elements (two diodes, a resistor and a capacitor) connected in parallel with electrical contacts. The roll of an additional diode and a resistor is to discharge the capacitor by the next making operation of the contacts. We describe here the interpretation of physical phenomena and the design principle of the circuit. We show the experimental confirmation of a relay, a thermal switch and a current fuse.**

Keywords—Electric contacts, Arc ignition, Relay, Fuse, Thermal switch, Initial arc, Transient current switch

Model of an Electric Arc for Circuit Analysis

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***Abstract*— This paper presents a mathematical model which describes the behavior of the electric arc in circuits. The model is compared with the classical Mayr-type model. Simulations and reals arcing cases are discussed for three common arcing situations. Results show the good performances of the presented model compared to Mayr-type models.**

Keywords—Electric Arc; Electric Arc Model; Circuit; Mayr Model; Shavemaker Model; Circuit Breaker; Arc fault; High Voltage Arcing;

12.2

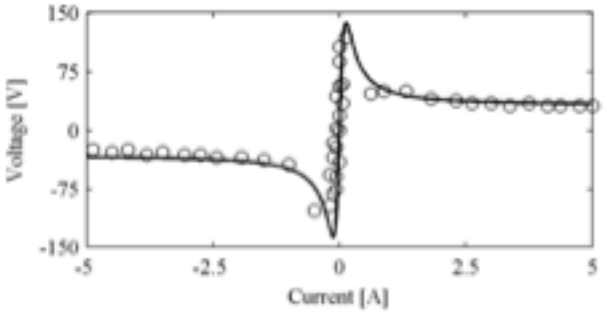


Fig. 5. Static discharge characteristic of an arc between two wires. The arc is initiated with a carbonized path. Dots are real data, the curve is the fit of the equation (10) with parameters α=49, β=1.46, γ=2221.

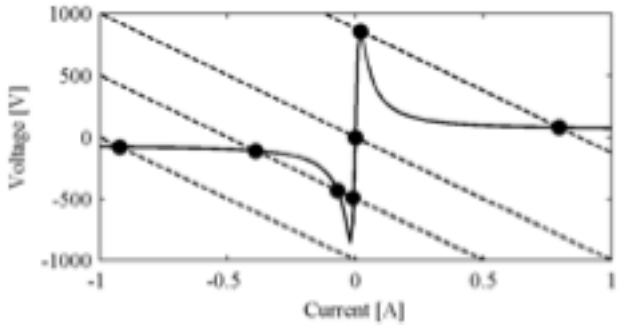
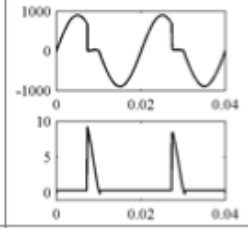
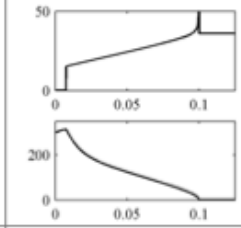
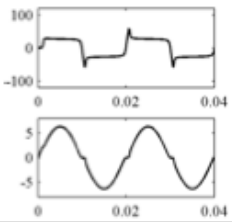
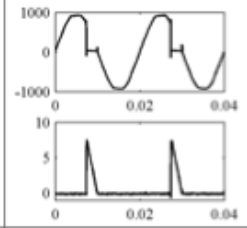
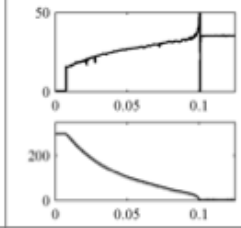
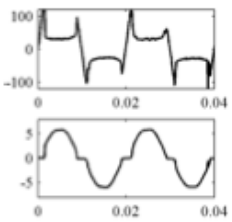
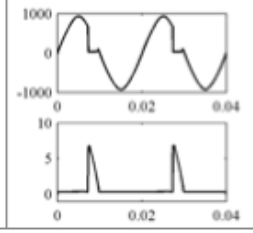
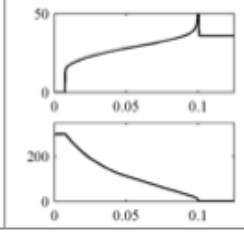
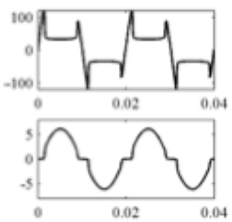


Fig. 6. Static characteristic and load lines. Load lines are drawn for four values of V_{DC}. So, depending on V_{DC}, it exists one, two or three crossing between the static characteristic and the load lines.

TABLE II EXPERIMENTAL AND SIMULATED ARC VOLTAGES AND CURRENTS

	Over Voltage Ignition	Open Contact Ignition	Carbonized Path Ignition
Shavemaker Model Current [A], Voltage[V]			
Experimental Data Current [A], Voltage[V]			
Mathematical Model Current [A], Voltage[V]			

12.4

Thermo-Mechanical Stress in Electrical Contacts due to Arcing Events

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Abstract—Silver tin oxide (Ag/SnO_2) contact materials are widely used for relays and contactor applications. A general trend in these applications is the steady miniaturization of switching devices, resulting in growing energy densities to be handled. The higher arcing energy densities in such new designs are inducing increased thermo-mechanical stresses in the contact material. As these stresses cannot be measured, FEM simulation was applied to make them visible for heavy duty break arcs. Based on these simulations and the understanding of the material stress behavior of the complete system (sub-assembly) significant improvements can be achieved.

As contact materials are process driven products, a new generation of Ag/SnO_2 materials with adopted stress release behavior was developed. Basis for these developments were thermo-mechanical FEM simulations on material behavior during processing and application. A particular focus in this optimization was placed on the rolling and cladding processes as final production steps. The significant improvements by optimized Ag/SnO_2 contact materials were finally proven by heavy duty endurance tests in contactor applications and have been benchmarked against other production technologies, e.g. sintered Ag/SnO_2 contacts.

Keywords—contact material; silver tin oxide; thermo-mechanical stress

13.1

A Synthetic Method for Photovoltaic Series Arc Fault Detection with Different Loads and Its Identification

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Abstract—Series arc fault that frequently occurs in photovoltaic (PV) generation system greatly reduces safety, economy and stability level of the operating system. However, factors as time-varying PV source caused by weather, outside electromagnetic interference especially from the inverter make PV series arc fault more complex to be detected.

This paper aims at providing a relatively reliable method for a new smart device called arc fault circuit interrupter (AFCI) to prevent PV system from threats by arc fault. In this paper, normal electric signals, fault electric signals and fault-like electric signals have been acquired via an experimental platform with PV system and different loads. Bringing PV series arc fault into the system, fault electric signals appear transient-state stage and steady-state stage which is also adjusted by inverter working mode. Fault-like electric signals have nearly the same transient process as fault electric signals. Euler method based on electric change and short time Fourier transformation (STFT) based on harmonic change are chosen to diagnose this kind of fault. A relatively satisfying synthetic algorithm based on a detection variable from each method has been proposed to identify fault conditions regardless of interference by fault-like conditions.

Keywords—photovoltaic series arc fault; synthetic detection method; fault-like conditions identification

13.2

Impact of Arc Root Mobility on Electrical Contact Life of Ag/SnO_2 Composite Rivets in DC Relay

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Abstract — To check the possible influence of arc root mobility on the contact erosion of composite rivets in DC automotive relay applications a model switch is designed to measure the arc root position with high time resolution. Seven different silver/tin oxide materials are examined under 70A inductive load – six of them manufactured by internal oxidation, one by powder metallurgy.

The experiments reveal a material transfer from anode to cathode for all materials. For most of the materials the results show a tendency to lower anode contact erosion with higher anode arc root mobility.

Comparing the materials to each other the finding is just vice versa: the materials with higher anode erosion show higher anode arc root mobility. Thus it is concluded that the main parameters for anode erosion are contact material properties as oxide content, manufacturing process, additives and oxide particle distribution.

While keeping these parameters constant, higher arc mobility usually comes along with lower contact erosion.

Keywords — Ag/SnO_2 contact materials, automotive relays, arc root mobility, material transfer, internal oxidation

14.3

Mechanism analysis of the electronic connector failure caused by micro-arc

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Abstract—As we know, electric erosion caused by arc would affect the reliability of contact, and there are many related researches and analysis results. But generally in the condition of low voltage and low current, the influences of arc are ignored. In this paper, a failure phenomena which happened on some electronic device was shown and the failure mechanism was analyzed. The results show that even voltage is lower 5V, arcing effect would also cause contact failure under certain conditions.

Keywords—arc; contact; failure; carbonize; lubricant

15.1

Contactless Connectivity

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***Abstract*— Emerging technologies are applied to create a new category of "contactless couplers". Various coupling options have been compared: ultrasound, high & low frequency RF, capacitive, optical, infrared and inductive coupling for power as well as data. TE Connectivity integrated state of the art Inductively Coupled Power Transfer (ICPT) technology with RF technology for data transfer into a M12 sized coupler-to-coupler prototype, and developed and released a M30 sized coupler system. This new connectivity system no longer has the limitations of physical contact based connectors, can increase productivity of existing industrial applications, and enables new applications. Latest developments focus on a higher frequency RF coupling capable of at least handling 1 Gbps data rates.**

Keywords*— *Contactless, Connectivity, Inductively Coupled Power Transfer (ICPT).

15.1

Fig. 1. a contactless coupler system, "coupler-to-coupler", M30 size

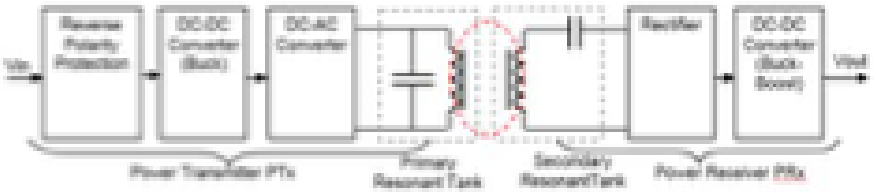

Fig. 6. Total power link of the contactless coupler pair.

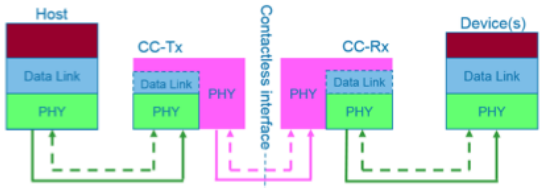

Fig. 3. Transparent contactless interconnection system.

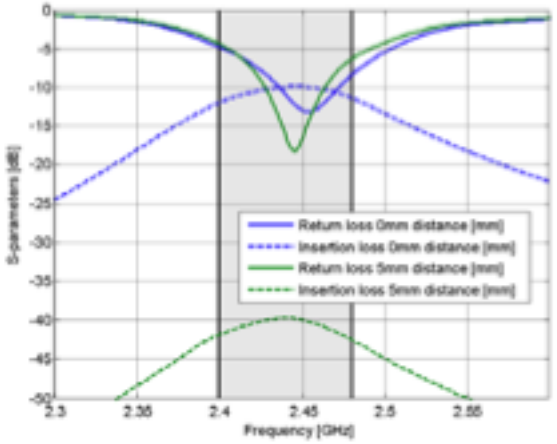

Fig. 16. Return loss and Insertion loss.

16.3

Device Optimization of Short-Circuiter for high AC and Impulse Currents

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Abstract—In electrical power systems and networks an immediate interruption is required at a fault in general. The interruption should lead to a safe state or to damage limitation for the installation and if applicable for service or maintenance staff too. However, under certain conditions, an interruption cannot be executed in time or all hazards cannot be controlled. In these cases, a permanent short-circuit is prepared or a safe interruption is initiated by a defined short-circuit. For self-protection of the electrical equipment used in installations, providing of a short-circuit state may be required in addition to interruption.

In particular surge protective devices (SPD) for high-capacity systems with short-circuit currents in the range of several 10 kA require in some cases a short-circuiter. The requirements for level and duration of short-circuit currents are described, which must be handled in fault cases. During normal operation, high impulse currents with already mentioned range of several 10 kA must be conducted several times safely, without compromising the functionality of the powerful short-circuiting device.

The optimization of a contact arrangement for reliable conducting of impulse and short-circuit currents in case of fault is carried out. Also the continuous current-carrying capacity of such arrangement by closing and conducting of high short-circuit currents is investigated. Optimization of forces required for the spring drive of the moving contact during flowing of high currents, which is based on FEM calculations, is shown. To evaluate the characteristics of arrangement, specific tests were performed in laboratory with high impulse and short-circuit currents.

In addition to overload protection function of overvoltage protective device further applications of such switchgear solution based on short-circuit function are represented.

Keywords—short-circuiter, spring drive, moving contact system, impulse current, short-circuit current, continuous current, FEM calculation, Lorentz force