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Chapter 1 : DISCHARGES AND ELECTRICAL INSULATION IN VACUUM. INTERNATIONAL SYMPOSIU

International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV) will be held at Greifswald, Germany, September , ISDEIV covers a wide range of scientific and technical areas including vacuum breakdown and flashover, vacuum arc physics, pulse power physics and technology, vacuum interrupters and other applications.

Emelianov Show Abstract While one is trying to create the model of high speed charged participle flows from the cathode spot in vacuum arcs, attention should be paid to the non-contradictory choice of boundary conditions system. Rosenthal; Isak Beilis; Samuel Goldsmith; Raymond Boxman Show Abstract Heat transfer to a thermally isolated graphite anode in a long duration vacuum arc was investigated. Anode bulk temperatures were measured as a function of time using two high temperature thermocouples. The anode surface temperature was optically determined. Surface temperatures of K were obtained in a A arc. A 1D non-linear heat flow model for the anode was developed. A solution was obtained using a dynamic numerical method and the effective anode potential was determined to be approximately 6 V. Pursch Show Abstract With the experiments presented in this paper applications of a retarding field analyzer for the measurement of ion potentials Ui in a vacuum arc plasma are discussed. The examined plasma was produced by a sinusoidal half-wave vacuum arc current. The experiments were concentrated on evaluating the plasma parameters at the last three milliseconds before current zero. In a current range from Arms to 10 kArms the ion potential distributions and their peak values were evaluated. With the increase of the arc current a decrease of the ion potential was found. By additional investigations of the angular distribution of the ion energies, a transition from a collision dominated interelectrode plasma to a freely expanding plasma was observed, depending on the arc current. Bruce Schulman Show Abstract The use of reduced gaps in applications of high-current vacuum arc devices presents a number of interesting challenges. Specifically, standard contact designs have been developed over several decades to achieve controlled motion of high-current ac arcs in vacuum interrupters. For medium-voltage applications, the optimal maximum contact gap can typically range from about 6 mm to about 2 cm. However, the influence of the contact design may be gap dependent, so additional research may be appropriate if the contacts are to be used at smaller gaps. For example, the current through spiral contacts produces a magnetic field perpendicular to the arc column, but this will force the arc to move outward and run along the periphery of the petals only if a threshold separation is achieved. In this investigation, a framing camera was used to record the appearance and motion of drawn vacuum arcs between spiral-petal contacts with final gaps of 2 to 3 mm. After the rupture of the molten bridge, a high-pressure arc column formed and expanded across the width of the spiral arm. At the reduced gap, an intense anode spot formed if the peak current exceeded approximately 15 kA. Compared to results previously obtained at larger gaps, the arc motion was greatly reduced, and severe contact damage was observed at lower currents. Schellekens Show Abstract In this paper, the high current vacuum arc behavior with horse shoe electrode has been described. These are dynamic vacuum arc distribution, the maximum current density related to the interrupting limit and factors which influences the interrupting limits. Then based on the above analyses, several vacuum interrupters within phi 70 mm outside diameter have been tested. From the results, it shows that the small size vacuum interrupters can be made with the oblique, ellipse shaped horseshoe electrode. The interrupting ability of such type vacuum interrupters is further increased. Shun Yuan; Jimei Wang Show Abstract This paper analyzes the effect of the gap of electrodes on the state of vacuum arc by experiment and theory. And the model of vacuum arc is set up. The optimal gap can be deduced from controlling the vacuum arc to be diffusion state, in order to get the optimal moving characteristics of electrodes. To solve these current questions, a new system was especially designs. The image converting High Speed Framing Camera, which combines a microscopical resolution of 5 micrometers with a nanosecond time resolution and a very high optical sensitivity. This camera was used to study the microscopical behavior of vacuum arc cathode spots in a pulsed high current arc discharge on copper. The direct observation of these spots with high resolution

revealed the conclusions that one single cathode spot, as normally observed by optical means consists of a number of simultaneously existing microscopical sub-spots, each of them with a diameter of about 15 micrometers and a mean distance of The mean existence time of these sub-spots on copper was found to be about 3. An upper limit of the crater surface temperature was estimated by a comparison between the brightness of a cathode spot and of a black body radiation lamp to about K. Dickinson Show Abstract Micron-size macroparticles can be removed from vacuum arc plasmas using magnetic filters, permitting the deposition of high-quality thin films of the cathode material. The principle of magnetic filtering is explained, and ways of improving filter efficiency using additional electric and magnetic fields are explored. Other problems such as down or upscaling of deposition facilities are briefly discussed. Otochin Show Abstract The present paper deals with the creation of a new mathematical model for 2D-computer simulation of the axisymmetrical radiative plasma magnitohydrodynamics MHD flows under vacuum spark discharge. Created MHD-model is based on implicit full conservative difference scheme in combined Eulerian and Lagrangian approach. The system of difference equations is solved by using of Newton-like iteration procedure. Groups of equations are selected in accordance with the similar character of physical processes and the energy balance calculation is carried out for the convergence control. Smeets; Honqun Li; Nico J. Lamerichs; Eiji Kaneko Show Abstract After interruption of a high-frequency hf current by a vacuum arc, two distinct types of reignition can be observed. The first type follows immediately after interruption, the second type tends to allow a currentless pause of a few tenths of a microsecond. The post-arc current that flows after hf-current interruption has been measured and has a peak of several A and a decay time of a several hundreds of ns. A dynamic sheath model for the decaying plasma after hf current interruption has been used successfully to model the measured post-arc current waveshapes. Nadja Vogel; Jan Heinzinger; Frank Cichos Show Abstract The cathode spot formation within first 22 ns was investigated by laser absorption photography and ps-pulse interferometry. The discharge was initiated between W-, Ag-, AuNi-, Pd- electrodes with cathode-anode distance below micrometers , the arc duration was some milliseconds and arc current 5 A. A ps-pulse holographic interferometer and momentary absorption photography enabled us to determinate spatial-temporal density distributions in the ignition phase of the cathode spot. An absolute electron density value of order of 3 - m-3 has been determined indicating high conductivity values of the metal vapor plasma. Present measurements show that cathode spot plasma is essentially non- ideal and verify theoretical calculations resulting in an ionization potential decrease in dense cathode plasmas. For random arc with a lower arc current, a model of single cathode spot with ion beam flux taking into account the cosine function spatial distribution is deduced. For arc steered by an external magnetic field, which is parallel to the cathode surface, a multiple cathode spots model is developed. And, in the case of random arc, calculation comparison between static substrate and rotating substrate is made. Results show that film thickness distribution is non-uniform when the arc is not controlled and tends to be uniform when the arc is steered by external parallel magnetic field with cathode geometry and substrate location being well chosen. Also, film thickness distribution is more uniform on a rotating substrate than on a static substrate. Hao Wang; Jiyan Zou; Mao-lin Li; Li-chun Cheng; Hong Lin Yang Show Abstract Characterization of the cathode spot, which connect to a vacuum dc arc on a consumable cathode as a source of material for deposition, is studied using a high speed photograph technique. For a titanium cathode, external magnetic field effects on the behavior of the cathode spot is given with respect to number, size, and motion. Lastly, some discussion to the experimental results are presented. Boruta Show Abstract The shield current distribution in a vacuum arc between CuCr40 contacts was studied by means of three cylindrical shields arrangement. It was found that the total shield current is affected by the arc mode. For a high-voltage oscillation sequence a significant effect on shield current distribution has an anode plasma jet. Bernd Gellert Show Abstract This report reviews research and development efforts within the last years for vacuum electron tubes, in particular power grid tubes for industrial applications. Physical and chemical effects are discussed that determine the performance of todays devices. Due to the progress made in the fundamental understanding of materials and newly developed processes the reliability and reproducibility

of power grid tubes could be improved considerably. Modern computer controlled manufacturing methods ensure a high reproducibility of production and continuous quality certification according to ISO guarantees future high quality standards. Some typical applications of these tubes are given as an example. Ladyzhensky Show Abstract Linear electric circuit with constant parameters becomes a nonlinear one with parameters variable in time after vacuum discharge gap is connected to it. Change of discharge parameters occurs by cycle. Full vacuum discharge cycle includes predischarge, spark, arc phases and current break phase Fig. Discharge development by incomplete cycle as well as development of one and the same discharge by several parallel channels with different cycles are possible. Every moment discharge current I is limited by one ofthe factors and namely - cathode emission ability L, plasma emission ability I, vacuum gap conductivity P. Fragment of the scheme Fig. Vozdvijenskii Show Abstract Switching characteristics of the triggered vacuum interrupter TVI combining the properties of vacuum interrupter and triggered vacuum switch are studied. In order to reduce the chopping current, electrode insertions made of a highly arcing-proof composite material are used. The effect of the load on the switching capability of the interrupter at the anode mode of operation is investigated. The obtained results make it possible to specify the requirements for trigger source output parameters with the aim to provide a reliable switching for different polarities of the main electrodes. Model tests of TVI in power frequency networks showed the possibility of its utilization under controlled switching with an accuracy to microsecond units and keeping all the properties of the vacuum interrupters. Vozdvijenskii Show Abstract The small-size sealed-off triggered vacuum switch TVS-7 designed to switch current pulse to 10 kA at high repetition rate to 1 kHz and maximum voltage to 25 kV is described. TVS switching characteristics are studied systematically versus the trigger current parameters for different polarities of the main electrodes. But in this case current and voltage oscillations occur at an initial discharge development stage. This unstable stage of discharge burning is subjected to investigation. A minimum trigger energy, of about 10 mJ is required to ensure stable conditions of discharge burning with any polarity at the main electrodes. Under the condition power losses at switch-on stage of the TVS are substantially reduced in comparison with those of traditional vacuum switches. This became possible because of the use of a two-stage trigger system of the erosion type and a small main vacuum gap. Ushakov Show Abstract The paper considers pulsed power repetitive systems using plasma opening switches. The solutions of a row of technical problems connected with both repetitive operation of accelerator having high peak power and x-ray radiation converter are proposed. These machines are to be prospective for advanced radiation technologies. Mega-ampere nanosecond current switching from external unstable light liner to inner load in vacuum on Angara Author s: Current instability and poor compression of the low mass liner were specific features of that inhoinogeneous Z-pinch. We treat the effect as a Plasma Opening Switch P05 process in external current shell of double pinch. Ulyanov Show Abstract The current switching by means of a gas-filled electron switch has been studied experimentally and theoretically. Under deep volume charge compensation conditions the switch showed complete controllability. The switched current density was more than current density of a similar vacuum switch by an order. Vladimir Bulan; Vladimir V. The PEOS parameters influence on the energy transfer efficiency was studied, the PEOS being considered as the part of the magnetically self- insulated line. Poulussen Show Abstract The vacuum state of vacuum switching elements after production is checked normally by Penning- or Magnetron methods combined electrical and magnetic field.

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Chapter 2 : DISCHARGES AND ELECTRICAL INSULATION IN VACUUM. INTERNATIONAL SYMPOSIU

28th International Symposium on Discharges and Electrical Insulation in Vacuum. We are pleased that the 28th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV) was successfully held at Greifswald, Germany, September ,

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More and more commercial vacuum circuit breakers have to switch capacitive currents in different networks. Further to line and cable charging circuits, single capacitor bank and back-to-back capacitor banks have to be switched with lowest frequency possible. Late breakdowns are potentially dangerous to the installation as they could lead to the build-up of high switching overvoltages that can be harmful to the equipments. IEC and IEEE standards define switching circuits with the main parameters of peak inrush current, inrush frequency and capacitive breaking currents. Real applications often deviate from these parameters. The paper presents the results obtained with a special designed vacuum interrupter designated for capacitive switching investigations. The test was performed at high power station. Various single-bank and back-to-back capacitor bank switching tests have been done with several inrush parameters and capacitor bank current values. The goal of the investigations was to make a statistical correlation between the late breakdowns and potential sources of failure. First is related to the energization of a capacitor bank by closing of a circuit breaker whereby a transient inrush current of up to several kiloamperes at higher frequency result. The second area is the interruption of the capacitive current. Generally, current interruption of few hundred amperes has a favourable effect on dielectric strength, but switching on inrush current during closing of vacuum interrupter causes significant decrease of breakdown voltage. The lost of vacuum interrupter insulation induced by NSDD or restrike phenomena was investigated for years with a particular concern relative to the capacitive switching [1, 2, 3, 4, 5, 6]. Several factors were identified as having influence on the late-breakdown capability: Nevertheless many published results are issued from the particular test with in-house arrangements. In this paper the results obtained with an experimental vacuum interrupter tested at high power test station are presented. The vacuum interrupter specially prepared was designed for the experimentation on capacitive switching in the aim of increased understanding of physical phenomena relative to the late breakdowns. The testing was carried out on a vacuum circuit breaker designated to 38kV rated voltage. On the first phase L1 of the circuit breaker the inrush current corresponding to back-to-back capacitive bank switching was applied. The peak value of inrush-current was 20kA, the inrush-frequency being Hz. The other two phases of the circuit breaker L2 and L3 see the inrush current as with a single capacitor bank switching test. During closing an inrush current of 6kA peak value and Hz frequency was reached. The capacitive breaking current was A. During the closing operation of capacitive switching the inrush current, testing voltage, pre-arcing time and contact travel were recorded. Special CuCr contact material has been used for testing. For back-to-back capacitive switching late breakdown probability of 0. The pre-arcing phase and late breakdown events were investigated from the point of view of field strength and breakdown time. Pre-arcing phase During closing operations, pre-arcs ignite on a fraction of the contact surface. The pre-arc time was measured for each closing operation corresponding to each phase of circuit breaker. The previous switching cycles is modifying the present contact surface during the test series. Figure 2 shows the pre-arc time observed in relation with the subsequent breaking operation. During contacts closing welds are formed due to the inrush current. When contacts are opened these welds are broken and macro-protrusions are formed on the contacts surface. These protrusions have a de-conditioning effect on the dielectric performance of vacuum interrupter. As can be seen in Figure 2, pre-arc time has a strong variation from shot to shot particularly for 20 kA inrush current. Nevertheless, the pre-arc time for back-to-back capacitive switching decreases slightly for the last 10 operations, exception the 20th one. The subsequent switching arc of A rated current seems to have a slight smoothing effect on the macro-protrusions. The pre-arc time for 6kA inrush current L2 and L3 phases is increasing after the first 7th operations and is keeping further almost a constant value. Pre-arc time in relation

with subsequent breaking operation for 20kA L1 phase and 6kA L2 and L3 phases inrush currents The macroscopic pre-arc field strength has been calculated for both values of 6kA L2 and L3 phases and 20kA inrush currents L1 phase. During the first 10 CO operations the values of macroscopic field strength of L1 phase are lower than for the other two phases L2 and L3, indicating that the local electric field strength is increased due to the presence of macro-protrusion, in concord with the observed longer pres-arc times. For the last 14th operations and following breaking arcs of A rated current a slight tendency of increasing of pre-arc field strength can be seen. It could indicate a smoothing effect on macro-protrusions during breaking operation, and thus a conditioning effect taking place during arc breaking at A rated current. Other authors [3, 7] have also noticed this comportment during capacitive switching for high rated current values. Pre-arc Field Strength vs. Figure 4 presents a picture of contacts surface after 24 operations of back-to-back Fig. Strong welding marks are prominent in the phase with back-to-back capacitive switching. Tips were formed on one of the contact surfaces whilst on the opposite contact surface craters have been developed. Protrusion with height up to 0. Contacts surface after 24 CO operations with 20kA inrush current a and 6 kA inrush current b. Late breakdown events Time periods of few ms between current zero of switching arc and peak recovery voltage means that dielectric post-arc behaviour is no more determined by the arc period. Late breakdowns events as function of breakdown voltage are presented in Figure 5. The switching operation which induced breakdown is also indicated close to each event point. In regard with the failure instant, three groups of late breakdown events have been identified: Late breakdowns taking place on the first peak of recovery voltage, that means around 10 ms time scale four late events ; Group 2: Late event in coincidence with the mechanical shock during opening, on the corresponding time scale of 20 ms; Group 3: Late events initiated on the further peaks of recovery voltage, the late breakdown time being of tens of ms. Late breakdown time versus the breakdown voltage. This cause of late discharge has been investigated by other authors in Ref [8]. For back-to-back capacitive switching L1 phase , the macroscopic field strength corresponding to the first peak of recovery voltage of switching arc has been calculated. In Figure 6 the switching arc field strength is indicated as function of the pre-arc time for each CO operation. The circle points represent the values of field strength during late breakdowns. Macroscopic field strength at the first peak value of capacitive recovery voltage versus pre-arc time for back-to-back capacitive switching. The circle points o represent the corresponding values for late breakdown events. Figure 6 indicates that breakdown field strength is not close related to the longer pre-arc time, thus with the higher macro-protrusion and higher microscopic local electric fields. This is an indication that electron field emission mechanism alone could not explain the late breakdown, other mechanisms need to be considered. The considered mechanism is charged particle induced breakdown. In the case of group 1 of events when instant breakdown is corresponding to the first peak of recovery voltage, it seems there are some coincidence between the duration of pre-arc and the number of late breakdowns. Longer pre-arcing time induces higher breakdown probability. More welds are produced for longer pre-arcs. After breaking at rated capacitive current there is a high probability to generate particle. This micro-particle can follow a single flight to the opposite contact and produce breakdown at the first peak voltage. This behaviour has been investigated by other authors in reference [7], the missing point is relative to the way the micro-particle is accumulating the energy. A possible explanation could be that the micro-particle, during its flight to the opposite contact, will be charged by the plasma sheath developed during the recovery period. Approaching the contact, the charge accumulated by particle will induce breakdown on the cathode by electron field emission. The potential mechanism can be the electron field emission by charged particle induced breakdown. The role of particle in relation with failure mechanism of circuit breaker is also discussed in reference [9]. In the case of group 3 , when the late events are initiated tens of ms after breaking current, micro-particles induced breakdown is a hypothesis of breakdown, as indicated by other authors [4, 6, 7, 9]. The charged micro-particle carries out iterative movements between the contacts under the capacitive recovery voltage. The number of iterative movements is dependent on particle position relative to the cathode as well of particle dimension. When the accumulated energy attains a certain value, the impact on the cathode can induce

breakdown. For the events of group 3 , the pre-arc time seems to be correlated with mean arcing time values, indicating that small welds is producing small particle being in movement into the inter-electrode gap. The particle induced breakdown mechanism is related to the particle dimension and its trajectory under a specified recovery voltage, as presented in [7, 9]. Most of the results could indicate that charged particle induced breakdown is the primary cause for late breakdown. Micro-particle is released by weld break-up or by mechanical shock during opening. The main problem of capacitive switching is welding. On Discharges and Electrical Insulation in Vacuum, pp. On Discharges and Electrical Insulation in Vacuum, p. On Power Delivery, Vol.

Chapter 4 : XXVth International Symposium on Discharges and Electrical Insulation in Vacuum

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Chapter 5 : Proceedings - International Symposium on Discharges and Electrical Insulation in Vacuum, ISD

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Chapter 6 : ISDEIV : XXVth International Symposium on Discharges and Electrical Insulation in Vacuum

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Chapter 7 : Our Team â€“ Vacuum Interrupters Ltd

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Chapter 8 : Meetings/Workshops on Plasma and Gas-discharge Physics in Germany

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