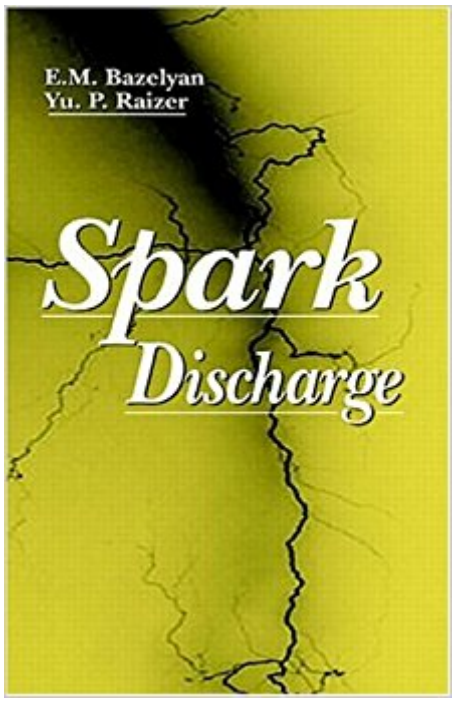
Spark Discharge



Synopsis

Spark Discharge is a first-of-its-kind text, providing a comprehensive and systematic description of the spark breakdown of long gas gaps. It discusses the nature of a long spark, physical peculiarities of relevant gas discharge processes, methods and results of experimental studies, and analytical and numerical models. The most important applications in high-voltage engineering are covered in a single volume. The straightforward presentation of complicated materials, the deep insight into the nature of the processes, and the simplified mathematical descriptions of the phenomena, make Spark Discharge an excellent textbook for students and an indispensable reference for researchers, physicists, and engineers.

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Customer Reviews

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Spark Discharge is a first-of-its-kind text, providing a comprehensive and systematic description of the spark breakdown of long gas gaps. It discusses the nature of a long spark, physical peculiarities of relevant gas discharge processes, methods and results of experimental studies, and analytical and numerical models. The most important applications in high-voltage engineering are covered in a single volume. Features: Gives an overview of the phenomena underlying the mechanism of spark discharge; classifies and generalizes experimental and theoretical models and gives a general

theory of the process; presents physically substantiated methods to solve problems in high-voltage engineering and lighting; contains original illustrative material that helps the reader understand the details of the space-time pattern of the process and important relations between spark parameters; and considers experimental methods and warns against common misunderstandings.

SPARK DISCHARGE (1997) by Edward M. Bazelyan and Yuri P. Raizer is an advanced text, requiring the reader to be well-grounded (pun intended) in calculus and electro-physics. Despite its broad title, the authors have sharply focused on the mechanism of the initiation and development of the spark discharge, which has not been so rigorously studied before. The mature, fully-formed spark or arc is mentioned only in passing, but one form or another of it may be found amply described in numerous other books, including a related volume by the same authors: Lightning Physics and Lightning Protection (2000), reviewed below. A further concentration is on the initiation of ultra-long discharges. Above a few megavolts, the lengths of individual discharges (in air) no longer have a direct relationship to the applied voltage or the proximity to nearby conducting surfaces, often traveling over a hundred meters horizontally only a few tens of meters above the ground, aptly illustrated by the photograph found on Page 4. Unfortunately, this is the only detailed picture of these spectacular artificial lightning bolts ÃƒÂ¢Ã â ¬Ã â œ the rest of the photographic illustrations are highly-technical close-ups, analyzing the details of the initial-discharge process. This is the main strength of the book ÃƒÂ¢Ã â ¬Ã â œ a microscopic examination of the mechanisms of the electrical breakdown of gases that allow the development and propagation of ÃƒÂ¢Ã â ¬Ã Å“superlong dischargesÃƒÂ¢Ã â ¬Ã Â•, as the authors refer to them.- * - Another strong point is the authorÃƒÂ¢Ã â ¬Ã â„¢s repeated emphasis on the shortcomings of existing research data, that of their own as well as othersÃƒÂ¢Ã â ¬Ã â„¢. This arises from the difficulties of controlling all the variables, so that there are differing results of apparently-similar or even apparently-identical experiments. They take great pains to describe the practical elements of the physical setup that affect its performance, such as the dependence of gap breakdown on the risetime and duration of the applied voltage being difficult to reproduce consistently, because of the effect the discharge-inception current has on the output voltage of the high-voltage source, not to mention the day-to-day changes in atmospheric pressure, temperature, and humidity. Each experimental setup is rigorously studied for sources of error. For a spherical electrode of radius r at a voltage U suspended by a thread over a plane electrode, the maximum electric field, E, is reduced by 5% compared to the theoretical value (U/r) even if the threadÃƒÂ¢Ã â ¬Ã â„¢s radius is only 1% of the sphereÃƒÂ¢Ã â ¬Ã â„¢s.- * - An important feature of the book is the many photographs

that were taken with an electron-optical image converter, a vacuum-tube device that produces extremely short exposures, as small as a fraction of a nanosecond, and intensifies faint light sources by thousands of times. This apparatus is briefly described in the text, and it allowed the authors to capture sharply time-resolved images of the constantly-changing faint streamers and leaders that were available by no other means. The EOIC consists of an optical lens that focuses an image of the discharge on the converterÃƒÂ¢Ã â ¬Ã â„¢s flat photocathode (located at one end of the converter). The photocathode emits a quantity of electrons proportional to the intensity of the light striking the photocathode at each point of the image. These electrons are accelerated and focused on an electronic shutter that controls the exposure time. Finally, the electrons admitted through the shutter are further accelerated and deflected to form a visible image on a fluorescent phosphor screen at the opposite end of the converter, similar to the CRT used in older televisions, except that the entire image is processed and displayed all at once, not raster scanned as in TV. This glowing image is in turn photographed with a conventional film or digital camera.- * - The authorsÃƒÂ¢Ã â ¬Ã â„¢ thesis provides an explanation of the ability of superlong discharges to span gaps far in excess of that predicted by the breakdown voltages measured for short gaps and lower voltages. The dielectric strength of dry air at STP is about 30 Kv/cm, as measured with sphere gaps using up to hundreds of kilovolts. This would extrapolate to a one meter gap for 3,000,000 volts, but in reality, it has been observed jumping well over a hundred meters. A graph of gap-distance vs. breakdown-voltage would have been useful here, showing the divergence of the unimodal relationship above whatever megavoltage the authors have determined from their research. A grossly-oversimplified description of the process (e.g. neglecting space-charge and some other effects) is that the discharge starts at the HV electrode, whose small radius concentrates the electric field to the point (~30 kv/cm) where the surrounding gas begins to ionize, forming a corona. Thin fingers (ÃƒÂ¢Ã â ¬Ã Å“streamersÃƒÂ¢Ã â ¬Ã Â•) extend from the corona, but draw only a small ionic current because they have a high resistance. As they extend, new streamers branch repeatedly from the initial ÃƒÂ¢Ã â ¬Ã Å“stemÃƒÂ¢Ã â ¬Ã Â•, each branch adding its tiny current to the (still very small) current in the stem, until finally the energy density in the stem portion is sufficient to ionize the air and significantly reduce its resistance. At this point, the branched streamer becomes a ÃƒÂ¢Ã â ¬Ã Å“leaderÃƒÂ¢Ã â ¬Ã Â•, and allows nearly the full electrode voltage U to appear at its tip, from which new streamers extend. As they branch in turn and their stems ionize, the leader advances behind them in a stepwise manner as the process is repeated, and possibly branches as well. Since the local field at the tip of leader is much more intense than the overall field from the electrode to the ground plane, the tip-field largely

predominates in determining the direction of propagation. Since the tip-field extends transversely as well as longitudinally, the discharge can meander widely, almost at random, rather than immediately heading to the ground by the shortest route possible. The authors take almost 300 pages to explain the mechanism properly, thoroughly, and going into exquisite detail at each step of the process. From them, I learned of a phenomenon of which I was previously unaware. In a normally-illuminated laboratory, I had thought that the hissing and sputtering I heard near an overvoltage-protection sphere gap on a 47 KV 60 Hz transformer was from a simple corona effect. But when I now observed it with all the lights off, I saw the play of thin pale blue streamers between the spheres as described by the authors, never developing into a short circuit because their resistance was too high. Or almost never ÃƒÂ¢Ã â ¬Ã â œ perhaps the rare arc-over was from a leader developing rather than an overvoltage spike reflected back from the load.- * - The book is well-written. L.N. SmirnovaÃƒÂ¢Ã â ¬Ã â„¢s English translation of the authorsÃƒÂ¢Ã â ¬Ã â„¢ Russian causes no problems for the reader, in spite of an occasional ÃƒÂ¢Ã â ¬Ã Å“quaintÃƒÂ¢Ã â ¬Ã Â• word usage and sentence structure (ÃƒÂ¢Ã â ¬Ã Å“ÃƒÂ¢Ã â ¬Ã Â|but sometimes it [the filamentary discharge] allows the researcher to admire it for a long timeÃƒÂ¢Ã â ¬Ã Â|ÃƒÂ¢Ã â ¬Ã Â•), and with only a few grammatical errors or typos (e.g. ÃƒÂ¢Ã â ¬Ã Å“ÃƒÂ¢Ã â ¬Ã Â|rises upÃƒÂ¢Ã â ¬Ã Â|ÃƒÂ¢Ã â ¬Ã Â•) that are found just as often in the work of American authors. The Table of Contents spans four pages and is logically organized to rapidly guide the reader to the desired information, although the section on experimental equipment and techniques is located in the middle of the book, rather than at the more conventional beginning or end. The 4-page Index is not quite so useful, as it is missing direct alphabetic entries for some significant terms like ÃƒÂ¢Ã â ¬Ã Å“ultracoronaÃƒÂ¢Ã â ¬Ã Â•, which is listed under ÃƒÂ¢Ã â ¬Ã Å“corona, ultracoronaÃƒÂ¢Ã â ¬Ã Â•, and there are no entries at all for terms like ÃƒÂ¢Ã â ¬Ã Å“arcÃƒÂ¢Ã â ¬Ã Â• or ÃƒÂ¢Ã â ¬Ã Å“arc flashÃƒÂ¢Ã â ¬Ã Â•, ÃƒÂ¢Ã â ¬Ã Å“ionization regionÃƒÂ¢Ã â ¬Ã Â• etc. To their credit, the authors are consistent in italicizing the first use of such terms in the body text. Minor variations in regional usage are easily decoded: the authors use of ÃƒÂ¢Ã â ¬Ã Å“stepwise leaderÃƒÂ¢Ã â ¬Ã Â• instead of ÃƒÂ¢Ã â ¬Ã Å“stepped leaderÃƒÂ¢Ã â ¬Ã Â• for instance. Other terms, such as ÃƒÂ¢Ã â ¬Ã Å“descending current-voltage characteristicÃƒÂ¢Ã â ¬Ã Â• is often better known as ÃƒÂ¢Ã â ¬Ã Å“negative resistance coefficientÃƒÂ¢Ã â ¬Ã Â• The line drawings, graphs, schematics, and tables, are all well-rendered, and present the concepts in a satisfactory manner.- * - Depending on the readerÃƒÂ¢Ã â ¬Ã â„¢s educational background and particular field of inquiry, Spark Discharge by itself may suffice to answer all their questions. For a less-advanced individual,

an additional, more basic text may be required to help them understand the electro-physical concepts that are presented here with little or no explanation. But this volume, combined with the one reviewed below, certainly was adequate for my needs in writing a treatise on the dangers of side-flashes from the grounding conductors of lightning protection systems, where the cableÃƒÂ¢Ã â ¬Ã â„¢s inductive impedance, even more than its resistance, can raise its potential at a few meters above the ground to millions of volts. This represents a very real, but often unrecognized, hazard for persons standing within reach of electricityÃƒÂ¢Ã â ¬Ã â„¢s leaping abilities ÃƒÂ¢Ã â ¬Ã â œ abilities that I now understand much more thoroughly.- * - I found two other reviews of this book on . The second, briefer one, stated that the text was short on equations and derivations and was more of an overview. I found exactly the opposite ÃƒÂ¢Ã â ¬Ã â œ each section went deeply into the underlying elecrto-physics, complete with derivations and the math to back them up. The only brief overviews were on topics beyond the scope of the book, such as natural lightning. More importantly, the authors point out whenever more research is needed. The first, longer, review commented on the non-standard form of the presentation, and while I agree with this description, I did not find it a particular problem.---------- LIGHTNING PHYSICS AND LIGHTNING PROTECTION (2000) by Edward M. Bazelyan and Yuri P. Raizer clearly shows its parentage, with ÃƒÂ¢Ã â ¬Ã Å“stepwise leadersÃƒÂ¢Ã â ¬Ã Â• developing from ÃƒÂ¢Ã â ¬Ã Å“streamersÃƒÂ¢Ã â ¬Ã Â•, but it is far more than a simple remake or reboot of Spark Discharge (1997). Like their earlier book, it is an advanced text, requiring the reader to be well-grounded (pun intended) in calculus and electro-physics. However, the final section on lightning protection is more practical and down-to-earth, and can be understood without all the math as long as the reader has grasped the basic concepts. This book deals with the mature, fully-developed discharge in the form of natural lightning. About 200 pages explain the initiation of the lightning discharge, using research from the authorsÃƒÂ¢Ã â ¬Ã â„¢ earlier work, but they take pains to modify it from Spark DischargeÃƒÂ¢Ã â ¬Ã â„¢s 300 pages covering laboratory artificial discharges, to insure that it applies to the much longer and more powerful natural bolts. They also carefully point out that the results from the smaller artificial discharges cannot simply be scaled up to hundreds-of-times longer lightning, and they detail the assumptions they made to modify their earlier findings. This is the best that anyone can do at present, because lightning cannot be had to order, nor studied and photographed with electron-optical image converters from a few feet away. They do include tests run on lightning ÃƒÂ¢Ã â ¬Ã Å“triggeredÃƒÂ¢Ã â ¬Ã Â• with small rockets

trailing several hundred feet of thin wire, but even these do not provide enough data for a complete understanding. There are still gaps in our knowledge of lightning that even it cannot jump.- * - Lightning protection is handled in the authorsÃƒÂ¢Ã â ¬Ã â„¢ unique style. It is not oriented to specific hardware or systems, but rather a description of the various components and how they interact with the lightning voltage and current. The reader will have to do some thinking to assemble a practical lightning protection system from the wisdom in this book, but it will be far better than off-the-shelf equipment hooked up by rote. The most interestingÃƒÂ¢Ã â ¬Ã Â|no, fascinating, part for me was the authorsÃƒÂ¢Ã â ¬Ã â„¢ explanation of lightningÃƒÂ¢Ã â ¬Ã â„¢s capricious, or even ÃƒÂ¢Ã â ¬Ã Å“mischievousÃƒÂ¢Ã â ¬Ã Â• behavior, exemplified by the striking (pun intended) photo on Page 21 of lightning hitting an all-metal television tower more than 600ÃƒÂ¢Ã â ¬Ã â„¢ below its tip. This is not an unusual case, and the bane of lightning-protection-system designers everywhere. Early experiments with lab-generated lightning, and scale model buildings and power lines, quickly proved unrealistic because natural discharges are two to three orders of magnitude longer, and bridge the gap by a somewhat different mechanism. Even today, there are texts that still refer to the ÃƒÂ¢Ã â ¬Ã Å“cone of protectionÃƒÂ¢Ã â ¬Ã Â• created by a lightning rod, or ÃƒÂ¢Ã â ¬Ã Å“tentingÃƒÂ¢Ã â ¬Ã Â• from an overhead guard wire. More enlightened tutorials use the ÃƒÂ¢Ã â ¬Ã Å“rolling-sphereÃƒÂ¢Ã â ¬Ã Â• method, which curves the straight surfaces of the ÃƒÂ¢Ã â ¬Ã Å“coneÃƒÂ¢Ã â ¬Ã Â• and ÃƒÂ¢Ã â ¬Ã Å“tentÃƒÂ¢Ã â ¬Ã Â• inward, reducing the protected volume. But this protection is only statistical ÃƒÂ¢Ã â ¬Ã â œ the occasional bolt will still penetrate this ÃƒÂ¢Ã â ¬Ã Å“shieldÃƒÂ¢Ã â ¬Ã Â•. The reason for this ability of lightning is complex, but well-described by the authors. As the nascent bolt descends from the clouds in the form of a stepwise (or ÃƒÂ¢Ã â ¬Ã Å“steppedÃƒÂ¢Ã â ¬Ã Â•) leader, it carries the cloudÃƒÂ¢Ã â ¬Ã â„¢s potential with it, increasing the strength of the electric field on the grounded objects below. Eventually, opposite-polarity ÃƒÂ¢Ã â ¬Ã Å“counterleadersÃƒÂ¢Ã â ¬Ã Â• arise from tall, narrow, structures or trees and stretch upward. [Note that many other texts use the term ÃƒÂ¢Ã â ¬Ã Å“upward streamerÃƒÂ¢Ã â ¬Ã Â• for the mature form of this discharge, although the initial streamers need to evolve into a leader in order to allow the ground charge to flow up them.] They usually connect to the downward leader some hundreds of feet above the ground, at which point the ÃƒÂ¢Ã â ¬Ã Å“return strokeÃƒÂ¢Ã â ¬Ã Â• starts. Note that the term ÃƒÂ¢Ã â ¬Ã Å“return strokeÃƒÂ¢Ã â ¬Ã Â• does not imply an immediate reversal of the current flow between could and ground, but only that the brightening of the lightning channel proceeds upward as the previously-deposited channel charge begins to move downward from the point of

connection. A similar effect is seen in a line of vehicles starting up as the traffic signal changes from red to green: the vehicles move forward, but the point of beginning of motion propagates rearward. The photo on Page 263 alone is worth the price of the book. It shows an unconnected 300ÃƒÂ¢Ã â ¬Ã â„¢ forked counterleader emanating from the top of the same television tower, while a lightning bolt completely ÃƒÂ¢Ã â ¬Ã Å“ignoresÃƒÂ¢Ã â ¬Ã Â• it, passing within 50 feet as it strikes the tower well below the tip. This, more than any written words, shows the fallacy of the ÃƒÂ¢Ã â ¬Ã Å“deflector-shieldÃƒÂ¢Ã â ¬Ã Â• concept of lightning protection systems, or attempts to develop special air terminals that promote the formation of counterleaders as a means of increasing their effective height. Percentage protection is the best one can do, but Thor and Zeus sometime beat the odds.- * - The book is well-written. L.N. SmirnovaÃƒÂ¢Ã â ¬Ã â„¢s English translation of the authorsÃƒÂ¢Ã â ¬Ã â„¢ Russian causes no problems for the reader, in spite of an occasional ÃƒÂ¢Ã â ¬Ã Å“quaintÃƒÂ¢Ã â ¬Ã Â• word usage and sentence structure (ÃƒÂ¢Ã â ¬Ã Å“Buildings of such a height can be said to fire lightning sparks up at the clouds rather than to be attacked by them.ÃƒÂ¢Ã â ¬Ã Â•), and with only a few grammatical errors or typos (e.g. ÃƒÂ¢Ã â ¬Ã Å“This often happens in heap [sic] rather than clouds carrying a relatively small electric charge.ÃƒÂ¢Ã â ¬Ã Â•) that are found just as often in the work of American authors. The Table of Contents spans four pages and is logically organized to rapidly guide the reader to the desired information. The 4-page Index is also extensive enough to be useful. A number of small black-and-white photographs of lightning strikes clearly show the characteristics being discussed, and some of the close-up EOIC pictures from Spark Discharge are included in the section on the initiation of the lightning discharge, with the caveat that the laboratory streamers and leaders may not be exactly the same as the ones involved in starting the natural version. I have described the EOIC in the above review of that book, along with a brief overview of the discharge initiation and propagation mechanism for laboratory sparks. The line drawings, graphs, schematics, and tables, are all well-rendered, and present the concepts in a satisfactory manner.- * - I found two other reviews of this book on . Both were 5-Star, but extremely short and contained no specific information or appraisals.- * - Taken together, Spark Discharge and Lightning Physics and Lightning Protection provide the best, most microscopically-detailed view of high-voltage discharge electro-physics published to date.

I was expecting more deatils in terms of equations and derivations of the material. This book was kept to an overview. I was not impressed.

This book is not for begninners, but for someone who already knows the basic stuff. The material is presented in a very ad-hoc manner. The chapters and subsections do not follow the standard "say what you are going to say - say - and say what you said" format. New concepts are thrown at you with no lead or introduction. But the material is there. So it is a good reference book. This book can use a good editor.