XLIII INTERNATIONAL SCIENTIFIC CONFERENCE ON INFORMATION, COMMUNICATION AND ENERGY SYSTEMS AND TECHNOLOGIES

ICEST

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Welcome
Conference
Authors
Papers

Proceedings of Papers

Serbia, Niš, June 25 - 27, 2008
Faculty of Electronic Engineering

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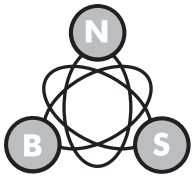

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Dear Colleagues,

I would like to welcome you to the International Scientific Conference on Information, Communication and Energy Systems and Technologies - ICEST 2008.

The conference is going to be held from June 25 to June 27, 2008, at the Faculty of Electronic Engineering, University of Niš, Serbia. The Conference is, for the seventh time, jointly organized by the Faculty of Electronic Engineering, Niš, Serbia; the Faculty of Telecommunications, Sofia, Bulgaria, and by the Faculty of Technical Sciences, Bitola, Macedonia. This is the third time that this big Balkan event takes place in Niš.

As to the earlier ICEST Conferences, many authors from institutions all over the Europe submitted their papers. This year, 169 papers have been accepted for oral (106 papers) or poster (63 papers) presentation.

After the Conference opening one plenary invited paper will be given by “Efficient Field Computation Based on N-Port Methods” from Franz Schlagenhaufer, University of Western Australia. Furthermore, a round table “Road to European University Educational Space” will be held. The Conference will also include special meeting related to Cooperation of Bulgaria, Macedonia and Serbia IEEE sections.

I hope that all participants will take opportunities not only to exchange their knowledge, experiences and ideas but also to make contacts and establish further collaboration. A social program, rich in events, will provide more relaxing atmosphere for meeting the colleagues.

I wish you successful presentations and pleasant stay in Niš!

On the behalf of the Technical Program Committee,

Prof. Dr. Bratislav Milovanović,
Conference Chairman

XLIII INTERNATIONAL SCIENTIFIC CONFERENCE ON INFORMATION, COMMUNICATION AND ENERGY SYSTEMS AND TECHNOLOGIES

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phone:	+381 18 529 205, 529 303
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TABLE OF CONTENTS

VOLUME 1

PLENARY SESSION

PL.1 **Efficient Field Computation Based on N-Port Methods ..... PIII**
F. Schlagenhaufer
The University of Western Australia, Australia

ORAL SESSIONS

TELECOMMUNICATION SYSTEMS

Invited papers:

TS.1 **IPTV Systems: Benefits, Challenges, and Future Trends 3**
Z. Bojković, B. Bakmaz, M. Bakmaz
University of Belgrade, Serbia

Regular papers:

TS.2 **Selection of Appropriate Technologies for Universal Service 8**
B. Bakmaz, N. Gospić, D. Bogojević, M. Davidović
University of Belgrade, Serbia

TS.3 **Impact of Cross Phase Modulation on WDM Optical Systems..... 12**
G. Georgiev, T. Levtchev, N. Stoyanov
Ministry of Interior, Bulgaria

TS.4 **Limitations in the Design of CATV Fiber-Optic Links 16**
L. Jordanova, D. Dobrev
Technical University of Sofia, Bulgaria

TS.5 **Improvement of the Optical Channel Noise Characteristics Using Distributed Raman Amplifiers 20**
L. Jordanova, V. Topchiev
Technical University of Sofia, Bulgaria

TS.6 **Method for Securing Pay TV Channels 24**
O. Panagiev
Technical University of Sofia, Bulgaria

TELECOMMUNICATION NETWORKS

TN.1 **The Optical WDM Network Link Failure Recovery Based on Bee Colony Optimization..... 31**
G. Marković, V. Aćimović-Raspopović, D. Teodorović
University of Belgrade, Serbia

TN.2 **SLA Monitoring System of QoS Parameters to Network Performance Metrics Mapping 36**
A. Tsenov, T. Georgiev*
Technical University of Sofia, Bulgaria
**TELELINK EAD, Sofia, Bulgaria*

TN.3 **End-to-End Delay Analyses in IP Networks..... 40**
R. Goleva, D. Atamian
Technical University of Sofia, Bulgaria

TN.4 **Analysis on Technologies Supporting Resource Management in Next Generation Networks 44**
P. Koleva, I. Atanasov, E. Pencheva
Technical University of Sofia, Bulgaria

TN.5 **Third Party Control in SIP Conferencing 48**
I. Atanasov, P. Koleva, E. Pencheva
Technical University of Sofia, Bulgaria

TN.6 **SIP Conference Policy Formalisms 52**
I. Atanasov, P. Koleva, E. Pencheva
Technical University of Sofia, Bulgaria

TN.7 **An Approach to Flow Control Based on Combined Adaptive Algorithm in Communication Networks 56**
G. Hristov, T. Iliev
University of Rousse, Bulgaria

TN.8 **A Model for Network Performance Analysis in a Case of Transfer a Large Image Files 60**
V. Aleksieva, P. Antonov
Technical University of Varna, Bulgaria

SIGNAL PROCESSING

SP.1 **Investigation of the FIR Filters in the Subtraction Method for Filtration of Power-line Interference in Case of Even Sampling 67**
G. Mihov, V. Manoev
Technical University of Sofia, Bulgaria

SP.2 **Application of Hausdorff's Window Fuction by Fir Filters Synhtesis 71**
P. Apostolov
Institute for Special Technical Equipment-MI, Sofia, Bulgaria

SP.3 **A New Method of Design of Variable Fractional Delay Digital Allpass Filters 75**
K. Nikolova, G. Stoyanov
Technical University of Sofia, Bulgaria

SP.4 **Multifractal Analysis of Outgoing Signal from the Statistical Multiplexer with Neural Network Control 79**
M. Zajeganović-Ivančić, I. Reljin*, B. Reljin*
ICT College, Belgrade, Serbia
**University of Belgrade, Serbia*

SP.5 **Document Decomposition Based on Recursive Radon Transform 83**
I. Draganov, R. Kountchev
Technical University of Sofia, Bulgaria

SP.6 **Enhanced Sound Capture System for Small Devices 87**
S. Mihov, T. Gleghorn*, I. Tashev*
Technical University of Sofia, Bulgaria
**Microsoft Corporation, USA*

SP.7 **The Application of Support Vector Machines for Classification of Audio Signals 91**
N. Reljin, D. Pokrajac
Delaware State University, USA

SP.8 **Investigation and Implementation of a Method Extracting and Recognizing of the Digitalized Voice Sequence 95**
V. Vučković, M. Stanković
University of Niš, Serbia

IMAGE PROCESSING

IP.1 **Adaptive Processing of Latent Fingerprints 101**
R. Kountchev, V. Todorov*, R. Kountcheva*
Technical University of Sofia, Bulgaria
**T&K Engineering, Bulgaria*

IP.2 **Multiscale Orientation Field Estimation 105**
B. Popović, M. Bandjur*, V. Stojanović**
Police Academy, Belgrade, Serbia
**Faculty of Technical Sciences, Kosovska Mitrovica, Serbia*
***University of Niš, Serbia*

IP.3 **Optimal Thresholds Selection for Adaptive Image Interpolation 109**
R. Mironov, R. Kountchev
Technical University of Sofia, Bulgaria

IP.4 **Non-uniform Threshold as an Alternative to Uniform Threshold in Denoising in Wavelet Domain 113**
M. Kostov, C. Mitrovski, M. Bogdanov*
University "St. Kliment Ohridski"-Bitola, Macedonia
**SS. Cyril and Methodius University, Skopje, Macedonia*

IP.5 **Statistical Analysis of Feature Vector Relevance in CBIR System 117**
G. Zajić, N. Kojić, N. Reljin, B. Reljin*
ICT College, Belgrade, Serbia
**University of Belgrade, Serbia*

IP.6 **Retrieving Images Using Content-Based Search and Progressive Wavelet Correlation 121**
I. Stojanović, S. Bogdanova*, M. Bogdanov*
University Goce Delcev, Macedonia
* *SS. Cyril and Methodius University, Skopje, Macedonia*

IP.7 **Flickering Reduction Algorithm in Anaglyph Stereoscopic Images 125**
A. Krupev, A. Popova
Technical University of Sofia, Bulgaria

IP.8 **Application of Geometrical Models for Face Detection 129**
D. Vasileva
Technical University of Sofia, Bulgaria

DIGITAL TELECOMMUNICATIONS

DT.1 **Influence of Fading Parameter on Performance of SC System over Rician Fading in the Presence of Interference 135**
M. Stefanović, D. Drača, A. Panajotović, D. Milović, N. Sekulović
University of Niš, Serbia

DT.2 **Influence of Imperfect Carrier Signal Recovery on Detection of QPSK Signal Using SC Technique in Rician Fading Channel 139**
Z. Mitrović, B. Nikolić*, G. Đorđević*
PD "HE Đerdap" d.o.o Kladovo, Serbia
**University of Niš, Serbia*

DT.3 **Analysis of EGC Diversity with Partially Coherent Weibull Fading Signals 143**
G. Đorđević, A. Cvetković, M. Stefanović
University of Niš, Serbia

DT.4 **Outage Probability of Dual-Hop Non-regenerative Relaying System over Weibull Fading Channels 147**
A. Cvetković, D. Milić, J. Anastasov
University of Niš, Serbia

DT.5 **Level Crossing Rate of Phase Process and FM Noise in Nakagami-q Fading Channel Influenced by Interference** **151**
M. Stefanović, M. Petković
University of Niš, Serbia

DT.6 **Performance of Convolutional/Single Parity Check Turbo Codes Over a Rician Fading Channel** **155**
S. Yordanova, N. Velikov*, G. Marinova
Technical University of Varna, Bulgaria
**Naval Academy "N. Vaptzarov" of Varna, Bulgaria*

DT.7 **An Analysis of the Channel Coding Performance in DVB-RCS Systems** **159**
T. Iliev
University of Rousse, Bulgaria

DT.8 **Analysis and Obtaining the Bit Error Rates (BER) in Turbo Code Decoder Algorithm** **163**
B. Stefanov
University of Rousse, Bulgaria

WIRELESS COMMUNICATIONS

WC.1 **Complex Baseband Model of Wireless OFDM Digital Communication System** **169**
M. Ovtcharov, V. Poulkov, G. Iliev
Technical University of Sofia, Bulgaria

WC.2 **Call-level Performance Modeling of Voice over IEEE 802.16 Systems** **172**
B. Tsankov, P. Koleva, K. Kassev, V. Poulkov
Technical University of Sofia, Bulgaria

WC.3 **Investigation of Bandwidth Request Mechanisms in 802.16 Networks** **176**
V. Hrisov
SouthWest University, Bulgaria

WC.4 **Localization System using RSSI Measurement of Wireless Sensor Network based on Zigbee Standard** **180**
M. Srbinovska, C. Gavrovski, V. Dimčev
SS. Cyril and Methodius University, Skopje, Macedonia

WC.5 **Wireless Sensor Networks: Performance Analysis in Indoor Scenarios** **184**
M. Srbinovska, V. Dimčev, C. Gavrovski
SS. Cyril and Methodius University, Skopje, Macedonia

WC.6 **One Easy-to-Implement Method for BER Performance Testing of Uncoded Ultrahigh Capacity (Gbit/s) Radio Link** **188**
M. Perić, D. Obradović, D. Perić, V. Orlić
IMTEL "Komunikacije" AD, Serbia

WC.7 **Exploring and Improving the Performance of Radio-Relay System Under Frequency-Selective Fading Channel** **192**
V. Orlić, M. Perić, M. Zečević
IMTEL "Komunikacije" AD, Serbia

CONTROL SYSTEMS I

CSI.1 **Designing a Compound Chaotic System Based on the Hide's Model** **199**
D. Chantov
Technical University of Gabrovo, Bulgaria

CSI.2 **Synchronization of Hyperchaotic Systems with Impermanent One-Variable Coupling** **203**
D. Chantov
Technical University of Gabrovo, Bulgaria

CSI.3 **Probability Stability and Monte Carlo Method 207**
B. Danković, B. Zlatković, B. Samardžić
University of Niš, Serbia

CSI.4 **An Experimental Setup for Studying Sampling and Signal Reconstruction Process 211**
M. Naumović, B. Petrović
University of Niš, Serbia

CSI.5 **Hardware Implementation of a Space Vector PWM Technique Using SystemC and VHDL Autocoding 215**
Ž. Mihajlović, M. Adžić*, E.Adžić
Faculty of Technical Scienses, Novi Sad, Serbia
**Technical Faculty in Subotica, Serbia*

CSI.6 **IR Thermographic Survey to Control-points Determination 219**
V. Videkov, A. Andonova, V. Manoev
Technical University of Sofia, Bulgaria

CSI.7 **Thermocontrol System for Refrigeration Camera 222**
V. Videkov, V. Manoev, S. Tabakov, M. Manoeva, C. Lazarov
Technical University of Sofia, Bulgaria

CONTROL SYSTEMS II

CSII.1 **Stepping Motor Drive for Precise Positioning Applications 227**
M. Mikhov, P. Nakov
Technical University of Sofia, Bulgaria

CSII.2 **Robust Position Control of Induction Motor Using Discrete-Time Sliding Mode Control 231**
B. Veselić, B. Peruničić-Draženović*, Č. Milosavljević
University of Niš, Serbia
**University of Sarajevo, Bosnia and Herzegovina*

CSII.3 **Education System for TV Monitors Adjustment with I2C Serial Bus Interface 235**
A. Bekiarski, A. Andreev
Technical University of Sofia, Bulgaria

CSII.4 **Fuzzy Logic Trajectory Control of Pneumatic Actuators for Rehabilitation Robot System 239**
N. Koceska, S. Koceski
University of L'\Aquila, Italy

CSII.5 **Vision-Based Guidance of a Six-Legged Robot 243**
A. Bekiarski, M. Milushev, P. Petrov
Technical University of Sofia, Bulgaria

CSII.6 **Camera Control for Active Surveillance from a Six-Leg Walking Machine 247**
M. Milushev, P. Petrov, O. Boumbarov, V. Georgieva
Technical University of Sofia, Bulgaria

CSII.7 **Dimension Computing of Rigid Group of Organism in Unknown Environment and Robot's Perception of the Physical World Structure 251**
B. Ristevski, V. Manevska, E. Vlahu-Georgievska, N. Rendevski
University "St. Kliment Ohridski"-Bitola, Macedonia

CSII.8 **Curiosity – A Base for Robots Learning and Development 255**
E. Vlahu-Georgievska, N. Rendevski, B. Ristevski
University "St. Kliment Ohridski"-Bitola, Macedonia

ELECTRONIC COMPONENTS, SYSTEMS AND TECHNOLOGIES

EL.1 **Application of Statistical Simulation Using SPICE to Parameter Extraction of RF Transistor Models 261**
E. Gadjeva, V. Durev
Technical University of Sofia, Bulgaria

EL.2 **Radio Frequency Power Bipolar Transistor Modeling and Simulation 265**
I. Nemingenchev, P. Petrova, B. Karapenev
Technical University of Gabrovo, Bulgaria

EL.3 **Equivalents of Optocouplers with a Photodynistor Photodetector 269**
E. Koleva, I. Kolev
Technical University of Gabrovo, Bulgaria

EL.4 **Reducing Switching Losses trough MOSFET – IGBT Combination 272**
V. Valchev, A. Van den Bossche*, A. Marinov
Technical University of Varna, Bulgaria
**Ghent University, Belgium*

EL.5 **Comparison of Nanocrystalline Magnetic Materials and Ferrites Used for Power Electronics Transformers 276**
V. Valchev, G. Nikolov
Technical University of Varna, Bulgaria

EL.6 **Development and Spice Simulation of Multiphase Full Bridge Transistor DC-DC Converter with Current Mode Control System 280**
G. Kunov, E. Gadjeva, M. Popov, N. Todorov
Technical University of Sofia, Bulgaria

EL.7 **Modern Technology Application in Electro Industry Parts Production 284**
S. Nusev, I. Andreevski, D. Temeljkovski*
University "St. Kliment Ohridski"-Bitola, Macedonia
**University of Niš, Serbia*

EL.8 **Research of Joint Operation of Hall Elements With Orthogonal Magnetic Sensitivity 288**
N. Draganov, A. Aleksandrov
Technical University of Gabrovo, Bulgaria

POWER TRANSMISSION AND DISTRIBUTION SYSTEMS

PS.1 **New Bare Conductor for Transmission and Distribution Overhead Lines of the Future 295**
Lj. Trpezanovski, A. Markoski
University "St. Kliment Ohridski"-Bitola, Macedonia

PS.2 **Transferred Potential from Substation HV/MV by MV Cable Line 299**
D. Tasić, M. Stojanović
University of Niš, Serbia

PS.3 **Investigation of the Noise Influence over Algorithms for Identification of the Air Power Line Parameters 303**
M. Todorova
Technical University of Varna, Bulgaria

PS.4 **Assessment of the Safety Conditions from High Touch and Step Voltages in the Grounding Systems of the mines 307**
N. Acevski
University "St. Kliment Ohridski"-Bitola, Macedonia

PS.5 **Marginal Loss Coefficients and Nodal Factor Method for Loss Allocation in Distribution Systems with DG 311**
M. Atanasovski, V. Borozan*
University "St. Kliment Ohridski"-Bitola, Macedonia
**SS. Cyril and Methodius University, Skopje, Macedonia*

PS.6 **Comparison of Production on a Cascade-Connected Hydro Power Plant, with Daily and Mounthly Reference 315**
M. Spirovski, A. Arsenov*, N. Acevski
University "St. Kliment Ohridski"-Bitola, Macedonia
** SS. Cyril and Methodius University, Skopje, Macedonia*

PS.7 **Dynamic Load Modelling of Some Low Voltage Devices 319**
L. Korunović, D. Stojanović
University of Niš, Serbia

PS.8 **The Analysis of Load Unbalance in Low Voltage Distribution Network of Niš 323**
D. Stojanović, L. Korunović
University of Niš, Serbia

ELECTROMAGNETISM IN MEDICINE

EMM.1 **Application of Appratus for Magnetotherapy together with Amplipuls in Medicine 329**
D. Dimitrov, B. Bonchev, A. Dimitrov
Technical University of Sofia, Bulgaria

EMM.2 **Application of Appratus for Magnetotherapy together with Apparatus for Permanent Electrical Field in Medicine 333**
D. Dimitrov, B. Bonchev, A. Dimitrov
Technical University of Sofia, Bulgaria

EMM.3 **Wavelet Transform Based ECG QRS Detector 337**
Y. Velchev, O. Boumbarov
Technical University of Sofia, Bulgaria

EMM.4 **Synthesis of Signals for Cranial Electrotherapy Stimulation 341**
N. Ralev
Technical University of Sofia, Bulgaria

EMM.5 **Microcontroller Based Device for Cranial Electrotherapy Stimulation 343**
N. Ralev
Technical University of Sofia, Bulgaria

VOLUME 2

MICROWAVE TECHNIQUE

MT.1 **Modeling of Step Discontinuity in Microstrip Structures by Using Wave Digital Approach 347**
B. Stošić, M. Gmitrović*
University of Niš, Serbia
**IMTEL "Komunikacije" AD, Serbia*

MT.2 **Modeling of Strip Conductors Centered between Ground Planes 351**
S. Musa, M. Sadiku
Prairie View A&M University, USA

MT.3 **TLM-Z Method Modelling of Microwave Cavity Loaded with Frequency-Dependent Dielectric Slab 355**
B. Milovanović, N. Dončov, J. Joković, T. Dimitrijević
University of Niš, Serbia

MT.4 **Balanced Amplifier Using Reduced Size Hybrids 359**
M. Nedelchev, I. Iliev
Technical University of Sofia, Bulgaria

MT.5 **Hybrid PKI Temperature Dependent Small-Signal Model of Microwave Transistors 363**
Z. Marinković, V. Marković
University of Niš, Serbia

MT.6 **Two Realizations of Active Transmitting Station at 13GHz Frequency Range 367**
P. Manojlović, S. Jovanović, N. Popović, S. Tasić, M. Perić
IMTEL "Komunikacije" AD, Serbia

MT.7 **Direct IQ Modulator for 38GHz Frequency Range 371**
S. Jovanović, A. Nešić, V. Orlić
IMTEL "Komunikacije" AD, Serbia

ANTENNAS AND PROPAGATION

AP.1 **Bandwidth Improvement of a Foursquare Microstrip Antenna 377**
S. Baev, N. Dodov
Technical University of Sofia, Bulgaria

AP.2 **Method for Measuring Parasitic Electromagnetic Emissions with Automated System for Measurement Management 380**
C. Levtchev, N. Stoyanov, G. Georgiev
Ministry of Interior, Bulgaria

AP.3 **Microstrip Antennas with EBG Structures 384**
N. Stoyanov, C. Levtchev, G. Georgiev
Ministry of Interior, Bulgaria

AP.4 **Analysis of Smart Antennas with URA Based on Half-Wavelength Dipoles-Simple DOA and ABF Methods 388**
V. Vassileva, S. Savov, M. Doneva
Technical University of Varna, Bulgaria

AP.5 **Hybrid empirical-neural model of the influence of foliage areas on EM propagation in urban environment 392**
Z. Stanković, M. Milijić, B. Milovanović, A. Marinčić*
University of Niš, Serbia
**Serbian Academy of Science and Art, Belgrade, Serbia*

COMPUTER SYSTEMS

COS.1 **CDMA Coded Wrapper-Based SoC Interconnect 399**
T. Nikolić, M. Stojčev
University of Niš, Serbia

COS.2 **Design of Leading Ones or Zeros Counting Circuit 403**
N. Milenković, V. Stanković
University of Niš, Serbia

COS.3 **Evaluation of CELL IBM Platform Regarding Development of Advanced Real-Time Video Algorithms 407**
N. Lukić, I. Papp, Z. Marčeta, D. Ačanski*, M. Temerinac
Faculty of Technical Sciences, Novi Sad, Serbia
**MicronasNIT, Novi Sad, Serbia*

COS.4 **Performing OLAP Operations in Data Cube with Dimensions Having Irregular Hierarchical Relationships 411**
A. Rozeva
University of Forestry, Bulgaria

COS.5 **Platform Independent-Information System Dependant Database Replication 415**
T. Stanković, M. Stanković*, D. Janković
University of Niš, Serbia
POWERSOFT d.o.o. Niš, Serbia

COS.6 **Human Performance Measurement in Interaction with Computer 419**
N. Đorđević, D. Rančić
University of Niš, Serbia

COMPUTER SYSTEMS AND INTERNET TECHNOLOGIES

CIT.1 **Responsive Pricing Model with Fixed Bandwidth Usage for the Next Generation Internet 425**
V. Radonjić, V. Aćimović-Raspopović
University of Belgrade, Serbia

CIT.2 **A Common Framework for Inter-Provider IP Quality of Service Specification 429**
S. Bosjančić, V. Timčenko, M. Stojanović
Mihajlo Pupin Institute, Serbia

CIT.3 **A Quickened Genetic Nonlinear Reconstruction Algorithm for EIT 433**
V. Guliashki
Institute of Information Technologies – BAS, Bulgaria

CIT.4 **Performance Comparison of Parallel Genetic Algorithms for Combinatorial Optimization Problems 437**
M. Lazarova, P. Borovska, S. Mabgar
Technical University of Sofia, Bulgaria

CIT.5 **Efficiency of Parallel Computations for Error Backpropagation Neural Network Training 441**
M. Lazarova
Technical University of Sofia, Bulgaria

CIT.6 **Time Histograms with Select and Zoom for Creating Visual Representation of Data Set for Managers 445**

S. Savovska, S. Loskovska*, V. Blazeski**
University "St. Kliment Ohridski"-Bitola, Macedonia
** SS. Cyril and Methodius University, Skopje, Macedonia*
***Prilepska pivara AD, Prilep, Macedonia*

POSTER SESSIONS

PO1 – TELECOMMUNICATIONS SYSTEMS AND TECHNOLOGY

PO1.1 **Pilot Signals Processing Module 451**
O. Panagiev
Technical University of Sofia, Bulgaria

PO1.2 **Comparative Analysis of VoIP Protocols Used in CATV Networks 455**
L. Jordanova, J. Nenkov
Technical University of Sofia, Bulgaria

PO1.3 **Location Based Services: Architecture, Mapping, Transportation GIS 458**
A. Samčović, Z. Bojković
University of Belgrade, Serbia

PO1.4 **Characteristics of Low-Voltage Installations as Transport Medium in Office Buildings 462**
J. Mandić-Lukić, D. Pokorni, N. Simić*
Energoprojekt – Entel, Serbia
**University of Belgrade, Serbia*

PO1.5 **Initial Direction of Arrival Estimation for Direction Lock Loop in DS/CDMA 466**
N. Denić, N. Milošević*, Z. Nikolić*
Serbian Armed Forces, Serbia
**University of Niš, Serbia*

PO1.6 **A Priority Traffic Models in Wideband Mobile Networks 470**
G. Balabanov, S. Mirtchev
Technical University of Sofia, Bulgaria

PO1.7 Application of Wireless Sensor Networks in Environmental Monitoring and Agriculture 474
N. Rendevski, V. Manevska, E. Vlahu-Georgievska, B. Ristevski
University "St. Kliment Ohridski"-Bitola, Macedonia

PO1.8 Evaluation of Frequency Hopping Spread Spectrum Signals Stability Against Impulse Disturbances 478
G. Cherneva, A. Andonov
Higher School of Transport "T.Kableshkov", Bulgaria

PO1.9 A Method of Generating Non-Uniform Square QAM by Using Non-Linear Amplification 480
D. Bojchev, D. Dobrev
Technical University of Sofia, Bulgaria

PO1.10 Analysis of the Opportunities for Reduction of Intercarrier Interference in OFDM 484
S. Kolev
Technical University of Sofia, Bulgaria

PO1.11 Analysis of Triple SC over Constant Correlated Rayleigh Signal and Interference Based on Signal to Interference Ratio 488
M. Stefanović, S. Panić, A. Mosić, S. Jovković
University of Niš, Serbia

PO1.12 Analysis of the SISO Decoding Algorithms 492
G. Hristov
University of Rousse, Bulgaria

PO1.13 Analysis of Model of Switched Non-uniform Scalar Quantization Model of Laplacean Source in a Dynamic Range of Power 496
Z. Perić, S. Panić, A. Mosić
University of Niš, Serbia

PO1.14 Reduction of Correction in Barrett's Algorithm 500
P. Stojanov, R. Dimova
Technical University of Sofia, Bulgaria

PO1.15 Level Crossing Rate of the SSC Combiner Output Signal in the Presence of Log-normal Fading 504
D. Krstić, P. Nikolić*, D. Stefanović, I. Temelkovski
University of Niš, Serbia
**Tigar Tyres, Serbia*

PO1.16 Outage Probability of SIR-Based Dual EGC Diversity Over Correlated Rayleigh Fading Channel 508
J. Anastasov, A. Cvetković, D. Stefanović
University of Niš, Serbia

PO1.17 Recovering Optical Image Transferred Through Atmospheric Turbulence. Wavelength analysis 512
K. Dimitrov
Technical University of Sofia, Bulgaria

PO1.18 The Research Results of Capacity Converter with Voltage Negative Impedance Converter 514
V. Draganov, Z. Stanchev, I. Tanchev
Technical University of Varna, Bulgaria

PO1.19 Investigation into Non-Recursive Digital Filter in Correlated Jamming Environment 518
B. Najdenov
Technical University of Varna, Bulgaria

PO1.20 Noise Modeling and Simulation for BJTS at Low Frequencies 522
P. Petrova, D. Petrov
Technical University of Gabrovo, Bulgaria

PO1.21 Computation of Capacitance of Circular Conductors 526
S. Musa, M. Sadiku
Prairie View A&M University, USA

PO2 - SIGNAL PROCESSING

PO2.1 **Evaluation of the Industry Standard Sampling Rates 533**
P. Petrov
Microengineering, Sofia, Bulgaria

PO2.2 **Sampling the Simplest Mathematical Functions 537**
P. Petrov
Microengineering, Sofia, Bulgaria

PO2.3 **Multiplication Products Quantization Noise Analysis for Orthogonal Complex IIR Digital Filters 540**
Z. Nikolova, D. Romanska
Technical University of Sofia, Bulgaria

PO2.4 **Investigation of the Phase-Voltage Responses of Digital Phase Detectors 544**
A. Yordanov, G. Kachakov, G. Mihov
Technical University of Sofia, Bulgaria

PO2.5 **Optimization of the Parameters of a Subwoofer with Phase-Inverter 546**
D. Damyanov, Y. Parvanova
Technical University of Sofia, Bulgaria

PO2.6 **LR-n Models for Voice Coil of the Loudspeaker Part I: Small Signal Analysis 550**
E. Sirakov
Technical University of Varna, Bulgaria

PO2.7 **Joint Source-Channel CELP Coding 554**
S. Pleshova-Bekiarska
Technical University of Sofia, Bulgaria

PO2.8 **MRI Enhancement on the Base of Morphological Processing 558**
V. Georgieva, A. Genova
Technical University of Sofia, Bulgaria

PO2.9 **Camera Calibration for Mechatronic Measurement 562**
A. Micić, B. Đorđević
University of Niš, Serbia

PO2.10 **Description of the Basic Algorithm for Glass Thickness Measurement by Laser Scanning 566**
G. Cmiljanović, D. Kukolj*, Z. Krajačević*
RT-RK Computer Based Systems LLC, Serbia
**Faculty of Engineering, Novi Sad, Serbia*

PO3 - COMPUTER SYSTEMS AND INTERNET TECHNOLOGIES

PO3.1 **The Octagon™ Embedded PCs and their Applications for Industrial Purposes 573**
G. Marinova, N. Kostov, S. Yordanova
Technical University of Varna, Bulgaria

PO3.2 **One Solution of Portable Pulse Generator Design 577**
B. Radin, P. Savković, B. Atlagić, D. Majstorović
Faculty of Technical Sciences, Novi Sad, Serbia

PO3.3 **Improved Architectural Support for Analysis and Design of Data Models 580**
P. Andreeva, S. Vassileva, V. Stoyanov
Bulgarian Academy of Sciences, Bulgaria

PO3.4 **Catalogue System for Electronic Documents Management and Control 584**
M. Karova, P. Grigorova
Technical University of Varna, Bulgaria

PO3.5 **Application of Genetic Algorithms for Effective Choice of Information 588**
H. Toshev, S. Koynov, C. Korsemov
Bulgarian Academy of Sciences, Bulgaria

PO3.6 Smart Interface Design and Web 2.0 application in the intelligent e-Learning Systems 592
D. Nedev
Jacobs University Bremen, Germany

PO3.7 Trends and Technologies for Web 2.0 Application Design 596
M. Ivanova
Technical University of Sofia, Bulgaria

PO3.8 RegPod v2.0 – Remote Data Access in Registry Base 600
M. Marinović, N. Micaković
ProCredit bank A.D., Serbia

PO4 - ELECTRONIC COMPONENTS, SYSTEMS AND TECHNOLOGIES

PO4.1 Photovoltaic Optocouplers 605
E. Koleva
Technical University of Gabrovo, Bulgaria

PO4.2 Germanium Photo Detectors 608
P. Rahnev, S. Letskovska
Burgas Free University, Bulgaria

PO4.3 A Simple FPGA/PLL Based Protocol Converter for Serial Data Transmission 610
B. Radin, P. Savković, D. Majstorović, B. Atlagić, S. Vukosavljev
Faculty of Technical Sciences, Novi Sad, Serbia

PO4.4 GPS/INS Vehicle Event Data Recorder 612
R. Miletiev, E. Iontchev*, R. Arnaudov
Technical University of Sofia, Bulgaria
**Higher School of Transport "T. Kableshkov", Bulgaria*

PO4.5 Low Frequency Measurement and Control of the Load Impedance 615
P. Angelov
Burgas Free University, Bulgaria

PO4.6 Intelligent Vizualizatoin of Total Harmonic Distortion in Frequency up to 10kHz 619
P. Angelov, M. Momchedgikov*
Burgas Free University, Bulgaria
** Technical University of Sofia, Bulgaria*

PO4.7 Effect of Electrodes Geometry on Self-Organization of Microdischarges in Dielectric Barrier Discharge 622
P. Dineff, D. Gospodinova, M. Shopov
Technical University of Sofia, Bulgaria

PO4.8 Effect of Electrodes Geometry on Technological Behavior of Dielectric Barrier Discharge 626
P. Dineff, D. Gospodinova, M. Shopov
Technical University of Sofia, Bulgaria

PO5 - CONTROL SYSTEMS

PO5.1 Virtual Instrumentation Software Applied to Calibration Procedure for Power Quality Meters 633
M. Simić, B. Dimitrijević
University of Niš, Serbia

PO5.2 Design of Two-channel Oscilloscope in LabView 637
R. Miletiev, P. Balzhiev
Technical University of Sofia, Bulgaria

PO5.3 Synthesis of Optimal Modal Controllers for DC Electric Drives 641
T. Georgiev, M. Mikhov*
Technical University of Varna, Bulgaria
**Technical University of Sofia, Bulgaria*

PO5.4 Television Image Filtering in Ship Model Analysis. Reduction of Noise Factors 645
M. Stefanova
Technical University of Varna, Bulgaria

PO5.5 Lighting System for SMD Optical Control 647
A. Stratev, V. Videkov
Technical University of Sofia, Bulgaria

PO6 - POWER TRANSMISSION, DISTRIBUTION SYSTEMS AND ELECTRICAL MACHINES

PO6.1 Using the Analytic Hierarchy Process in Load Growth Forecast 653
B. Stevanoski, A. Arsenov*
University "St. Kliment Ohreidski"-Bitola, Macedonia
** SS. Cyril and Methodius University, Skopje, Macedonia*

PO6.2 Investigation of Power Line Regime Parameters in Case of Switching over with Switch Gears in Electrical Networks 20 kv 656
M. Vasileva, M. Hamza, A. Filipov
Technical University of Varna, Bulgaria

PO6.3 Using of MATLAB Simulink for Education in High Voltage Technics and Electrical Safety 660
M. Vasileva, M. Yordanova
Technical University of Varna, Bulgaria

PO6.4 Influence of the Loss of Voltage onto the Quality of Road Lighting 663
Z. Ivanov
Technical University of Sofia, Bulgaria

PO6.5 Application of Neural Networks for Analysis in Bolted Busbar Connections of New Design 666
S. Yordanova, R. Tzeneva
Technical University of Sofia, Bulgaria

PO6.6 Implementation of TASE.2, MMS and APLI Protocols 670
N. Savić, M. Popović, B. Atlagić, M. Temerinac*
Faculty of Technical Sciences, Novi Sad, Serbia
**MicronasNIT, Novi Sad, Serbia*

PO6.7 Self-excitation of an Induction Generator – Mathematical Model and Experimental Verification 674
M. Radić, Z. Stajić
University of Niš, Serbia

PO7 - EDUCATION QUALITY

PO7.1 Application of Digital Circuits' Simulation in Academic Exercise Classes-Methodology Issues and Results 681
G. Marinova, N. Kostov, S. Yordanova
Technical University of Varna, Bulgaria

PO7.2 Analysis of Matched Filters in MATLAB Environment 684
V. Georgieva, M. Neikova
Technical University of Sofia, Bulgaria

PO7.3 Education in Microelectronics Design Using a Web Environment 686
R. Radonov
Technical University of Sofia, Bulgaria

PO7.4 Computers Optic Microscopy for Education Electronics 688
S. Letskovska, P. Rahnev
Burgas Free University, Bulgaria

Effect of Electrodes Geometry on Technological Behavior of Dielectric Barrier Discharge

Peter D. Dineff[1], Dilyana N. Gospodinova[2], and Momchil G. Shopov[3]

Abstract – **Effect of electrodes geometry on technological behavior of dielectric barrier discharge, or the interaction between microdischarges and their own current's magnetic field, discussed in this paper, has been revealed only recently. It is responsible for the formation of very different microdischarge patterns, volt-ampere characteristics, and operating regimes of plasma-chemical surface functionalizing.**

Keywords – **dielectric barrier discharge, microdischarges, volt-ampere characteristic, true power, critical voltage.**

I. Introduction

Self-organization of microdischarges appears to be a strong effect and dominant feature of the dielectric barrier discharge. The underlying memory and repulsion effects thus create quasi-Coulomb crystal patterns in *DBDs*, [1].

The short duration of microdischarges leads to a very low overheating of the streamer channel, and the DBD plasma remains strongly non-thermal. The principal microdischarge properties for most of the frequencies depend not on the characteristics of the external circuit, but just on the gas composition, pressure, and electrode geometry and configuration.

Electrode geometry and configuration is in position to provoke various schemas of electromagnetic interaction between microdischarges into a regular structure and the magnetic field of currents through electrodes.

This electrodes geometry effect (*EGE*) needs a change in microdischarges self-organization, and different "crystal" patterns in *DBDs*. It exerts strong influence on the breakdown conditions and avalanche transformation into a streamer that modify the DBD volt-ampere characteristic $I_{avg} = f(U_{rms})$, breakdown (burning) voltage U_b , and true power P and power factor (cosine of the phase difference) of oxygen and nitrogen operating areas, Fig. 1a.

The true power P is a criterion of dissociation, ionization, and chemical reaction processes in air at atmospheric pressure. It can be determined quantitatively by calculating it (for quasi-harmonically changing supply voltage) from the experimentally plotted volt-ampere characteristic of *DBDs*, Fig. 1b.

[1]Peter D. Dineff is with the Faculty of Electrical Engineering of the Technical University of Sofia, 1756 Sofia, Bulgaria, e-mail: dineff_pd@abv.bg .

[2]Dilyana N. Gospodinova is with the Faculty of Electrical Engineering of the Technical University of Sofia, 1756 Sofia, Bulgaria, e-mail: dilianang@abv.bg .

[3]Momchil G. Shopov is with the Faculty of Electrical Engineering of the Technical University of Sofia, 1756 Sofia, Bulgaria, e-mail: elmax@abv.bg.

The aim consists in identifying *EGE* or the influence of the magnetic field of currents through electrodes upon microdischarges patterns by means of the *DBDs* true power technologic characteristic: $P = \varphi(U_{rms})$.

II. Experimental Investigations

The electrode geometry and configuration, combined with the way of power supply to the electrodes, and the magnetic properties of electrodes define the strong interaction between microdischarge and electric currents passing through the electrodes themselves.

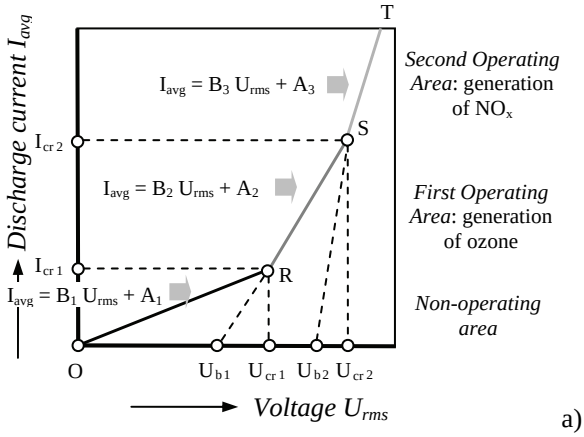

Fig. 1. Volt-ampere electrical characteristic (**a**) and technological characteristic (b) of *DBD* with first (or oxygen) operating stage *RS*; and second (or nitrogen) operating stage *ST*.

For a quasi-harmonic law of changing the supply voltage U (50 Hz) there exists the following relationship (*RS* and *ST*):

$$P = U_b \left(I_{avg} - I_{cr} \right) \tag{1}$$

$$I_{avg} = B U_{rms} + A \tag{2}$$

$$P = U_b \left(B\, U_{rms} + A - I_{cr} \right) \tag{3}$$

$$P = D\, U_{rms} + C; \qquad D = U_b\, B; \qquad C = A - I_{cr} \tag{4}$$

The ionization of the gas as well as all the chemical changes occurring in it and on the surface treated are conducted with electron exchange, which allows using the true power as a technologic characteristic, because the true electrical energy is proportional to the quantity of electricity carried through the discharge gap:

$$E = Pt = U_b \left(I_{avg}\, t - I_{cr}\, t \right) = U_b \left(Q - Q_{cr} \right) \tag{5}$$

where Q_{cr} is the critical quantity of electricity not causing ionization and chemical changes in the discharge gap.

The exhibition of *EGE* on the technological behavior of *DBDs* is investigated experimentally on two flat-parallel electrode systems – *the first one*, with square electrodes: 150 × 150 mm, S = 225 cm^2, *the second one* – with rectangular electrodes: 75 × 300 mm, S = 225 cm^2 (with the same area), for two different distances *d* (3 and 6 mm) and different manner of electrodes power supply, Fig. 3.

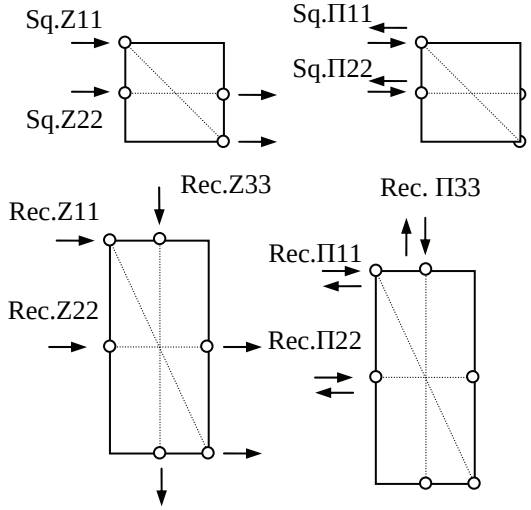

Fig. 2. Various schemes of electrodes power supply to the flat-parallel electrodes having a square or rectangular shape. One of the taps shown is connected to the lower electrode, and the other to the upper one.

Investigations are performed with two types of electrodes, namely by using non-magnetic (made of aluminum) or magnetic (made of cold-rolled electrical steel) electrodes. The magnetic electrodes should also change the discharges pattern and technological characteristics of *DBDs*. The dielectric barrier is made of alkaline glass of thickness *b* = 3 mm.

The external (volt-ampere) characteristic of *DBDs*, representing the relationship between the average value of discharge current I_{avg} and the root mean square value of the voltage applied across the discharge gap U_{rms}, reflects not only the existence of those two characteristic burning regimes of *DBDs*, but also all the influences on elementary processes in the discharge gap, Fig.1, [2].

III. Results and Discussions

The volt-ampere characteristics of *DBDs* have been plotted experimentally, discharge models have been worked out in accordance with [2], and according to Fig. 1b, for a minimal coefficient of linear correlation, not lesser than 0.9850, and then all the parameters of the non-operating area, first and second *DBD* operating areas have been calculated.

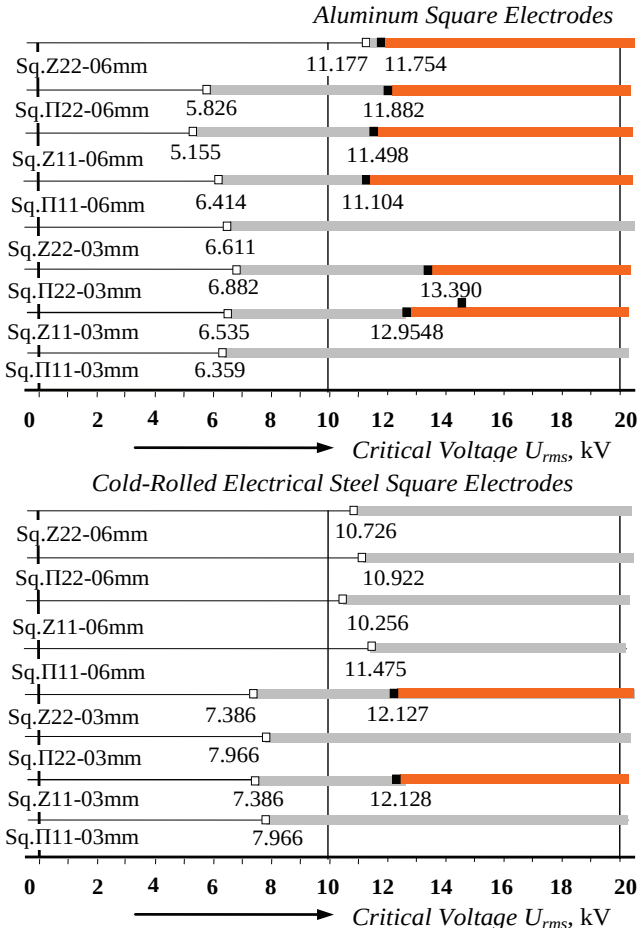

Fig. 3. Operating burning regimes of *DBDs* with square aluminum, and cold-rolled electrical steel electrodes, different discharge gaps and electrodes power supply schemes (Z--, or П--), according to Fig. 2 – critical voltages $U_{cr,1}$ and $U_{cr,2}$ (RMS).

The electrode shape (square or rectangular), way of "discharge-current" interaction ("Z" or "П"), and characteristic manner of power supply (11, 22, or 33) exert substantial impact on the change in the main critical parameters of ignition and burning of *DBDs*, including critical voltages $U_{cr,1}$ and $U_{cr,2}$, Figs. 3 and 4.

For square electrodes, irrespective of the size of discharge gap *d*, using of iron electrodes leads to an increase in the critical voltage $U_{cr,1}$, Fig. 3, whereas for rectangular electrodes the exactly opposite phenomenon is observed – a decrease in the critical voltage $U_{cr,1}$ (to the exclusion of scheme Rec.П33-0.6 mm), Fig. 4.

The second (nitrogen) operating regime occurs in only 19 of all the 40 cases investigated (i. e. in ca. 48 % of them), Figs. 3 and 4.

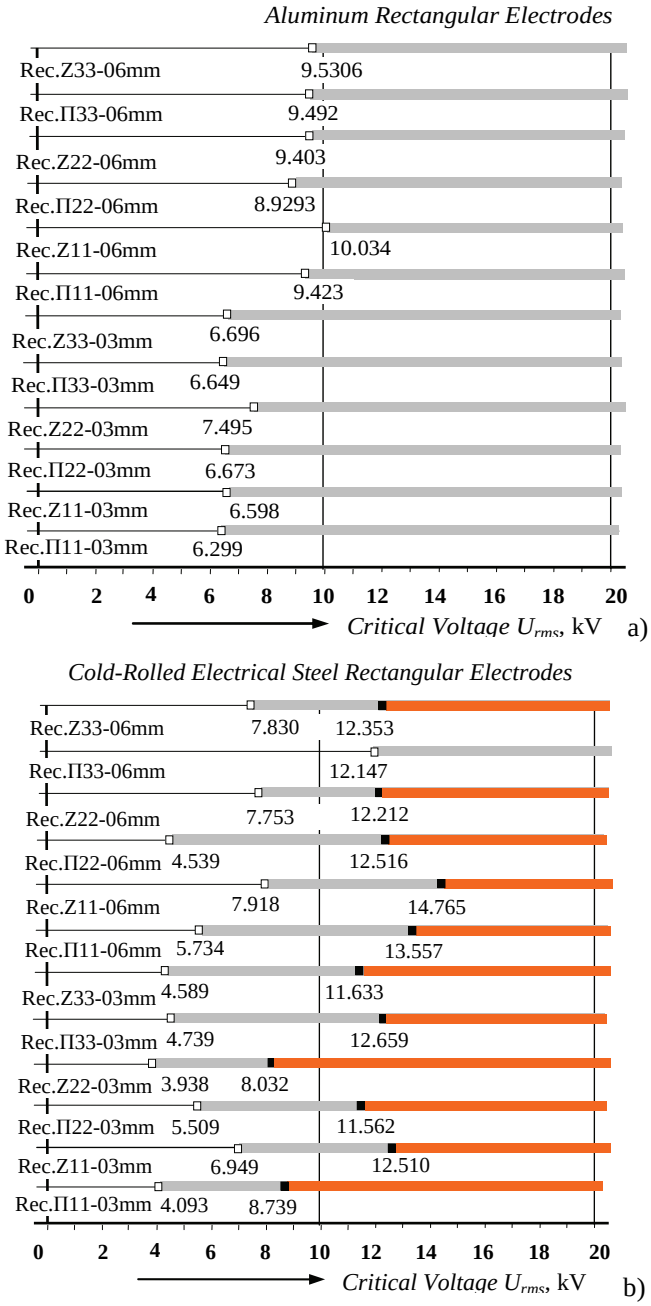

Fig. 4. Operating burning regimes of *DBDs* with square aluminum (a), and cold-rolled electrical steel electrodes (b), different discharge gaps and electrodes power supply schemes (Z--, or П--), according to Fig. 2 - critical voltages $U_{cr,1}$ and $U_{cr,2}$ (RMS).

An answer should be given to the basic question: Will the *EGE* observed be practically advantageous when priority is given to operating regimes with high specific true power, i. e. true power per a unit of area or $p_V = P/V$; $V = S.d$?

The rectangular electrodes offer better and more various applications not only for a discharge gap of 3 mm, but also for that of 6 mm: *first*, for a discharge gap of 3 mm both the aluminum and cold-rolled electrical steel electrodes provide higher specific true powers – above 200 mW/cm^3, Figs. 5 and 6; *second*, for a discharge gap of 6 mm both the aluminum and cold-rolled electrical steel electrodes provide higher specific true powers – above 150 ÷ 200 mW/cm^3.

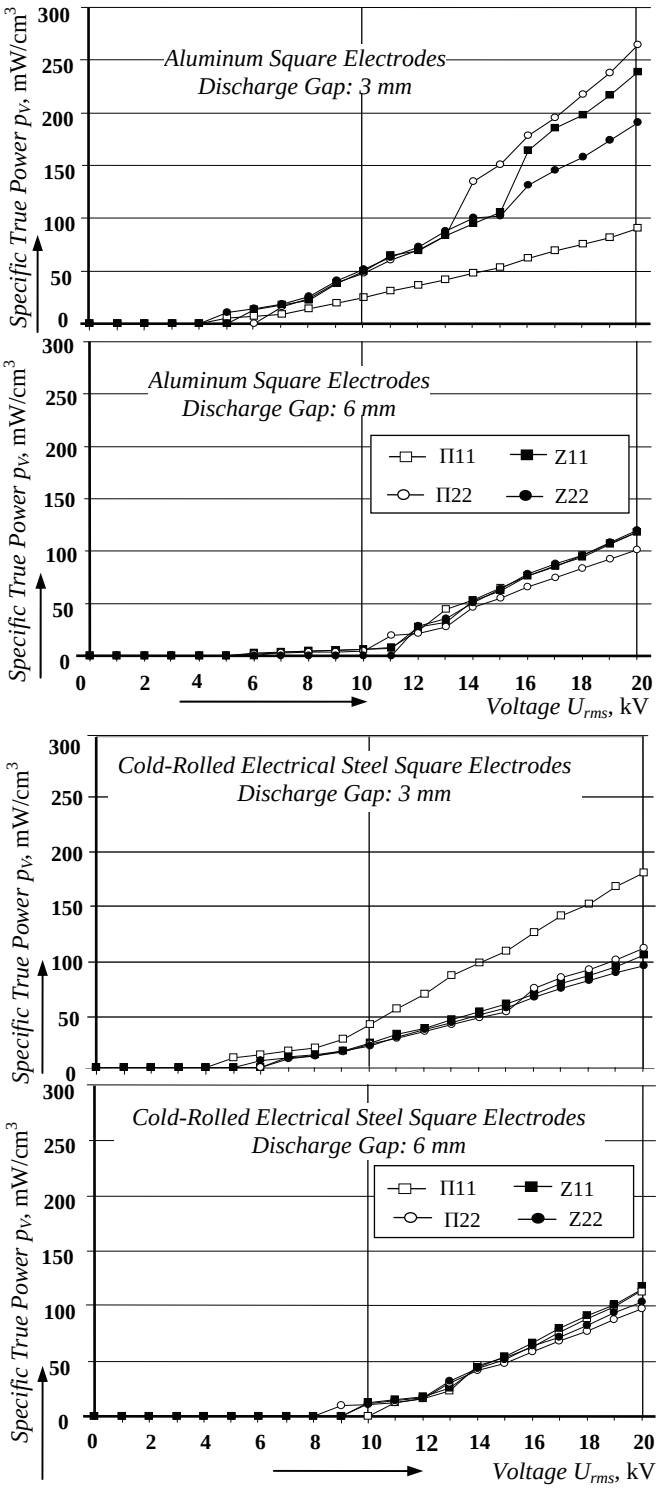

Fig. 5. Technological characteristics of operating burning regimes of *DBDs*, $p_V = \varphi(U_{rms})$, with square aluminum, and cold-rolled electrical steel electrodes, different discharge gaps and electrodes power supply schema (Z--, or П--), according to Fig. 2.

The magnetic electrodes allow realizing the ignition of *DBDs* at lower voltages – for square electrodes made of aluminum the minimal critical ignition voltage $U_{cr,1}$ is 5.155 kV; for square electrodes made of steel it is 7.386 kV; for rectangular electrodes made of aluminum this voltage is 6.299 kV,

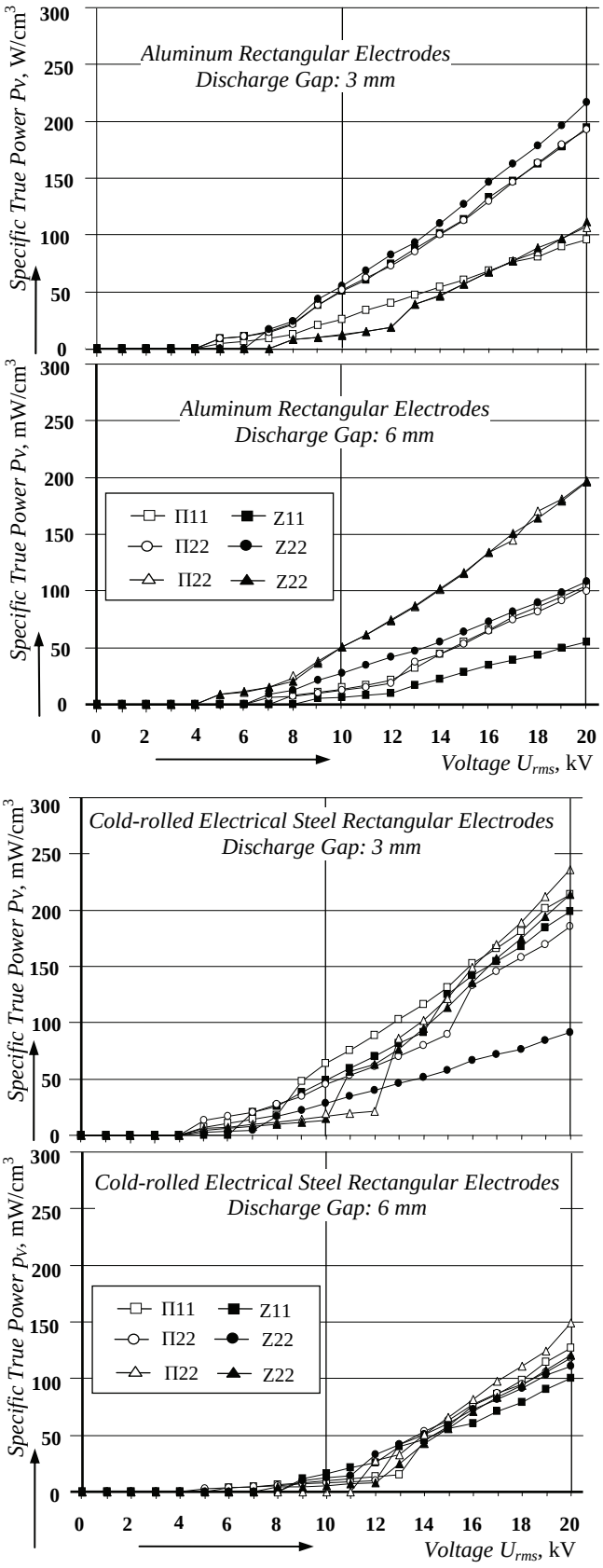

Fig. 6. Technological characteristics of operating burning regimes of *DBDs*, $p_V = \varphi\ (U_{rms})$, with rectangular aluminum and cold-rolled electrical steel electrodes, different discharge gaps and electrodes power supply schemes (Z--, or П--), according to Fig. 2.

whereas for rectangular electrodes made of steel its values is 3.938 kV. The minimal critical ignition voltage $U_{cr,2}$ (oxygen operating regime) for square electrodes made of aluminum is 11.104 kV; for square electrodes made of steel it is 12.128 kV; for rectangular electrodes made of aluminum there is no such operating regime, whereas for rectangular electrodes made of steel the minimal critical ignition voltage is 8.032 kV, Figs. 3 and 4.

The experimental setup of the investigation performed unambiguously reveals the dependence of the elementary processes in *DBDs* from its own magnetic field. Introducing a ferromagnetic medium (electrodes) into the discharge area also influences the conducted elementary processes, their development being stimulated in some cases and suppressed in others.

IV. Conclusion

As a result of the experimental investigations performed for two geometrical shapes (square and rectangle), various schemes of power supply and materials of the electrodes - magnetic and non-magnetic, the following main conclusions can be derived:

- the electrode geometry effect, which consists in the geometry impact, manner of power supply (and magnetic or non-magnetic material) of the electrodes, does exist and can be successfully applied to creating *DBDs* plasma technological systems;

- a positive technologic effect should be sought not only in the direction of increasing the specific true power p_V in each of the two operating areas – oxygen and nitrogen operating regime of surface plasma treatment and functionalization, but also regarding the diminishment of respective critical ignition voltages $U_{cr,1}$ and $U_{cr,2}$.

- the electrode geometry effect is a hidden form of electromagnetic interactions and their impact upon the elementary processes in *DBDs*.

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AUTHOR INDEX

A
Acevski, N., 307, 315
Aćimović-Raspopović, V., 31, 425
Ačanski, D., 407
Adžić, E., 215
Adžić, M., 215
Aleksandrov, A., 288
Aleksieva, V., 60
Anastasov, J., 147, 508
Andonov, A., 478
Andonova, A., 219
Andreev, A., 235
Andreeva, P., 580
Andreevski, I., 284
Angelov, P., 615, 619
Antonov, P., 60
Apostolov, P., 71
Arnaudov, R., 612
Arsenov, A., 315, 653
Atamian, D., 40
Atanasov, I., 44, 48, 52
Atanasovski, M., 311
Atlagić, B., 577, 610, 670
B
Baev, S., 377
Bakmaz, B., 3, 8
Bakmaz, M., 3
Balabanov, G., 470
Balzhiev, P., 637
Bandjur, M., 105
Bekiarski, A., 235, 243
Blazeski, V., 445
Bogdanov, M., 113, 121
Bogdanova, S., 121
Bogojević, D., 8
Bojchev, D., 480
Bojković, Z., 3, 458
Bonchev, B., 329, 333
Borovska, P., 437
Borozan, V., 311
Bosjančić, S., 429
Boumbarov, O., 247, 337
C
Chantov, D., 199, 203
Cherneva, G., 478
Cmiljanović, G., 566
Cvetković, A., 143, 147, 508
D
Damyanov, D., 546
Danković, B., 207
Davidović, M., 8
Denić, N., 466
Dimčev, V., 180, 184
Dimitrijević, B., 633
Dimitrijević, T., 355
Dimitrov, A., 329, 333
Dimitrov, D., 329, 333
Dimitrov, K., 512
Dimova, R., 500
Dineff, P., 622, 626
Dobrev, D., 16, 480
Dodov, N., 377
Dončov, N., 355
Doneva, M., 388
Drača, D., 135
Draganov, I., 83
Draganov, N., 288
Draganov, V., 514
Durev, V., 261
Đ
Đorđević, B., 562
Đorđević, G., 139, 143
Đorđević, N., 419
F
Filipov, A., 656
G
Gadjeva, E., 261, 280
Gavrovski, C., 180, 184
Genova, A., 558
Georgiev, G., 12, 380, 384
Georgiev, T., 36, 641
Georgieva, V., 247, 558, 684
Gleghorn, T., 87
Gmitrović, M., 347
Goleva, R., 40
Gospić, N., 8
Gospodinova, D., 622, 626
Grigorova, P., 584
Guliashki, V., 433
H
Hamza, M., 656
Hrisov, V., 176
Hristov, G., 56, 492
I
Iliev, G., 169
Iliev, I., 359
Iliev, T., 56, 159
Iontchev, E., 612
Ivanov, Z., 663
Ivanova, M., 596
J
Janković, D., 415
Joković, J., 355
Jordanova, L., 16, 20, 455
Jovanović, S., 367, 371
Jovković, S., 488
K
Kachakov, G., 544
Karapenev, B., 265
Karova, M., 584
Kassev, K., 172
Koceska, N., 239
Koceski, S., 239
Kojić, N., 117
Kolev, I., 269
Kolev, S., 484
Koleva, E., 269, 605
Koleva, P., 44, 48, 52, 172
Korsemov, C., 588
Korunović, L., 319, 323
Kostov, M., 113
Kostov, N., 573, 681
Kountchev, R., 83, 101, 109
Kountcheva, R., 101
Koynov, S., 588
Krajačević, Z., 566
Krstić, D., 504
Krupev, A., 125
Kukolj, D., 566
Kunov, G., 280
L
Lazarov, C., 222
Lazarova, M., 437, 441
Letskovska, S., 608, 688
Levtchev, C., 380, 384
Levtchev, T., 12
Loskovska, S., 445
Lukić, N., 407
M
Mabgar, S., 437
Majstorović, D., 577, 610
Mandić-Lukić, J., 462
Manevska, V., 251, 474
Manoev, V., 67, 219, 222
Manoeva, M., 222
Manojlović, P., 367
Marčeta, Z., 407
Marinčić, A., 392
Marinković, Z., 363
Marinov, A., 272
Marinova, G., 155, 573, 681
Marinović, M., 600
Markoski, A., 295
Marković, G., 31
Marković, V., 363
Micaković, N., 600
Micić, A., 562
Mihajlović, Ž., 215
Mihov, G., 67, 544
Mihov, S., 87
Mikhov, M., 227, 641
Milenković, N., 403
Miletiev, R., 612, 637
Milić, D., 147
Milijić, M., 392
Milosavljević, Č., 231
Milošević, N., 466
Milovanović, B., 355, 392

Milović, D., 135,
Milushev, M., 243, 247
Mironov, R., 109
Mirtchev, S., 470
Mitrović, Z., 139
Mitrovski, C., 113
Momchedgikov, M., 619
Mosić, A., 488, 496
Musa, S., 351, 526
N
Najdenov, B., 518
Nakov, P., 227
Naumović, M., 211
Nedelchev, M., 359
Nedev, D., 592
Neikova, M., 684
Nemingenchev, I., 265
Nenkov, J., 455
Nešić, A., 371
Nikolić, B., 139
Nikolić, P., 504
Nikolić, T., 399
Nikolić, Z., 466
Nikolov, G., 276
Nikolova, K., 75
Nikolova, Z., 540
Nusev, S., 284
O
Obradović, D., 188
Orlić, V., 188, 192, 371
Ovtcharov, M., 169
P
Panagiev, O., 24, 451
Panajotović, A., 135
Panić, S., 488, 496
Papp, I., 407
Parvanova, Y., 546
Pencheva, E., 44, 48, 52
Perić, D., 188
Perić, M., 188, 192, 367
Perić, Z., 496
Peruničić-Draženović, B., 231
Petković, M., 151
Petrov, D., 522
Petrov, P., 243, 247, 265, 533, 537
Petrova, P., 522
Petrović, B., 211
Pleshova-Bekiarska, S., 554
Pokorni, D., 462
Pokrajac, D., 91
Popov, M., 280
Popova, A., 125
Popović, B., 105
Popović, M., 670
Popović, N., 367
Poulkov, V., 169, 172
R
Radić, M., 674
Radin, B., 577, 610
Radonjić, V., 425
Radonov, R., 686
Rahnev, P., 608, 688
Ralev, N., 341, 343
Rančić, D., 419
Reljin, B., 79, 117
Reljin, I., 79
Reljin, N., 91, 117
Rendevski, N., 251, 255, 474
Ristevski, B., 251, 255, 474
Romanska, D., 540
Rozeva, A., 411
S
Sadiku, M., 351, 526
Samardžić, B., 207
Samčović, A., 458
Savić, N., 670
Savković, P., 577, 610
Savov, S., 388
Savovska, S., 445
Schlagenhaufer, F., PIII
Sekulović, N., 135
Shopov, M., 622, 626
Simić, M., 633
Simić, N., 462
Sirakov, E., 550
Spirovski, M., 315
Srbinovska, M., 180, 184
Stajić, Z., 674
Stanchev, Z., 514
Stanković, M., 95, 415
Stanković, T., 415
Stanković, V., 403
Stanković, Z., 392
Stefanov, B., 163
Stefanova, M., 645
Stefanović, D., 504, 508
Stefanović, M., 135, 143, 151, 488
Stevanoski, B., 653
Stoianov, P., 500
Stojanović, D., 319, 323
Stojanović, I., 121
Stojanović, M., 299, 429
Stojanović, V., 105
Stojčev, M., 399
Stošić, B., 347
Stoyanov, G., 75
Stoyanov, N., 12, 380, 384
Stoyanov, V., 580
Stratev, A., 647
T
Tabakov, S., 222
Tanchev, I., 514
Tashev, I., 87
Tasić, D., 299
Tasić, S., 367
Temeljkovski, D., 284
Temelkovski, I., 504
Temerinac, M., 407, 670
Teodorović, D., 31
Timčenko, V., 429
Todorov, N., 280
Todorov, V., 101
Todorova, M., 303
Topchiev, V., 20
Toshev, H., 588
Trpezanovski, Lj., 295
Tsankov, B., 172
Tsenov, A., 36
Tzeneva, R., 666
V
Valchev, V., 272, 276
Van den Bossche, A., 272
Vasileva, D., 129
Vasileva, M., 660, 656
Vassileva, S., 580
Vassileva, V., 388
Velchev, Y., 337
Velikov, N., 155
Veselić, B., 231
Videkov, V., 219, 222, 647
Vlahu-Georgievska, E., 251, 255, 474
Vučković, V., 95
Vukosavljev, S., 610
Y
Yordanov, A., 544
Yordanova, M., 660
Yordanova, S., 155, 573, 666, 681
Z
Zajeganović-Ivančić, M., 79
Zajić, G., 117
Zečević, M., 192
Zlatković, B., 207