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Datum: **Sarajevo, 24. novembar 2014. godine**
Predmet: ***Prijava teme doktorske disertacije – III ciklus studija***

Poštovani,

S obzirom da su ispunjeni svi uvjeti predviđeni nastavnim planom i programom u okviru Bolonjskog koncepta doktorskog studija, a koji su u skladu s Pravilima studiranja za treći ciklus studija i Zakonom o visokom obrazovanju Kantona Sarajevo, obraćam se zahtjevom da Vijeće doktorskog studija osnuje komisiju za razmatranje prihvatljivosti predložene teme i određivanje mentora/supervizora tokom pripreme doktorske disertacije s radnim naslovom:

„Modeliranje pojava u tlu oko pobuđenog uzemljivača uključujući međuzavisnost raznorodnih poljā"

Također, potrebno je da Vijeće izvrši imenovanje nastavnika - mentora/supervizora i zakaže termin odbrane prijedloga teme doktorske disertacije.

Obzirom na kompetentnost i bliskost materiji, koja će biti predmet istraživanja disertacije, za mentora/supervizora pri izradi doktorske disertacije predlažem **red.prof.dr.sci. Rasim Gačanović, dipl.el.ing.** koji je bio i akademski savjetnik pri definiranju uže oblasti doktorske teze i okvirnog koncepta teme doktorske disertacijem odnosno supervizor prilikom izrade prijave prijedloga teme doktorske disertacije (projekta). Također, saglasnost na ovaj prijedlog dali su red.prof.dr.sci. Hamid Zildžo, dipl.el.ing., - blizak oblasti računarskih metoda - alatu koje će biti korišten za modeliranje zadanog problema i red.prof.dr.sci. Sead Berberović, dipl.el.ing., profesor na Fakultetu elektrotehnike i računarstva, Sveučilište u Zagrebu.

Uz prijavu prijedloga teme doktorske disertacije prilažem obrazloženje prijedloga teme doktorske disertacije sa slijedećim dokumentima:

1. Biografija kandidata;
2. Pregled stanja u oblasti istraživanja;
3. Motivacija i ciljevi za istraživanje;
4. Metodologija i plan istraživanja;
5. Očekivani znanstveni doprinos disertacije;
6. Pregled osnovne - startne literature.

S poštovanjem,

Mario Kokoruš, m.sc.ee

Prijavu podnio:
Mario Kokoruš

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1. CURRICULUM VITAE

Osobni podaci

Prezime (ime oca) ime	Kokoruš (Saša) Mario
Datum i mjesto rođenja	1. mart 1987., Visoko
Državljanstvo	Bosna i Hercegovina
Adresa stalnog boravka	Naselje Luke 4 B2L2/3, 71300 Visoko
E-mail	mkokorus@yahoo.com

Obrazovanje

- Juli 2010. – MA (MoE – Master) – Magistar elektrotehnike – Diplomirani inženjer elektrotehnike, odsjek elektroenergetika, Univerzitet u Sarajevu;
- Juni 2008. – BA (BoE – Bakalaureat/Bachelor) – Inženjer elektrotehnike, odsjek elektroenergetika, Univerzitet u Sarajevu;
- Maj 2005. – Srednja tehnička škola *Hazim Šabanović* Visoko;
- Maj 2001. – Osnovna škola *Safvet-beg Bašagić* Visoko.

Profesionalna aktivnost kandidata

- Septembar 2010. – Decembar 2010. – Srednja tehnička škola *Hazim Šabanović* Visoko – Profesor na predmetima *Osnove elektrotehnike 1*, *Osnove elektrotehnike 2*, *Elektrotehnički materijali*, *Električne mašine*;
- Decembar 2010. – Decembar 2011. – *Arcelor Mittal Zenica* – Inženjer elektroodržavanja u departmentu Aglomeracija;
- Mart 2012. – Juli 2013. – *Energoinvest d.d. Sarajevo* – Projektant visokonaponskih trafostanica;
- Juli 2013. –... – *Bosanskohercegovački komitet Međunarodnog vijeća za velike električne sisteme CIGRÉ* – Generalni sekretar.

Projekti

1. **Trafostanica 132/33/11 kV, 2012/2013.** - Kurdistan, New Harir – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja (dispozicija, kontrolna zgrada, rasplet kablova i kablovske police, kondenzatorska baterija, kućni transformator 11/0.4 kV...), projektiranje šema; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Mart 2012. - Juli 2013. godine;
2. **Trafostanica 132/33/11 kV, 2012/2013.** - Kurdistan, Shaqlawa – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja (dispozicija, kontrolna zgrada, rasplet kablova i kablovske police, kondenzatorska baterija, kućni transformator

11/0.4 kV...), projektiranje šema; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Mart 2012. - Juli 2013. godine;

3. **Trafostanica 132/33/11 kV, 2012/2013.** - Kurdistan, Rezan – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja (dispozicija, kontrolna zgrada, rasplet kablova i kablovske police, kondenzatorska baterija, kućni transformator 11/0.4 kV...), projektiranje šema; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Mart 2012. - Juli 2013. godine;
4. **Trafostanica 132/33/11 kV, 2012/2013.** - Kurdistan, Koya – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja (dispozicija, kontrolna zgrada, rasplet kablova i kablovske police, kondenzatorska baterija, kućni transformator 11/0.4 kV...), projektiranje šema; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Mart 2012. - Juli 2013. godine;
5. **Proširenje trafostanice 132/33/11 kV, 2012/2013.** - Iraq, Soran – Projektiranje elektromontažnih rješenja; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, August 2012. - Maj 2013. godine;
6. **Trafostanica 220/60 kV, 2013.** - Alžir, Touggourt 2 – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Januar 2013. - Juli 2013. godine;
7. **Trafostanica 220/60 kV, 2013.** - Alžir, Touggourt 2 – Projektiranje uzemljenja, projektiranje elektromontažnih rješenja; Energoinvest d.d. Sarajevo, Injženjering za elektroenergetiku, Sarajevo, Januar 2013. - Juli 2013. godine;
8. **FAT (Factory Acceptance Test) mjernih transformatora 145 kV, 2013.** - Dijagnostička ispitivanja strujnih i naponskih transformatora, KONČAR, Mjerni transformatori d.d. Zagreb, Maj 2013. - April 2014.;
9. **Remont željezare, 2011.** - Remont asinhronih motora maksinalne snage 200kW, remont elektroormara sklopno-zaštitne opreme, Arcelor Mittal Zenica, Department Aglomeracija, Juli 2013. godine;
10. **Puštanje u pogon sinhronog motora 5MW, 2011.** - Arcelor Mittal Zenica, Department Aglomeracija, Juli 2013. godine;
11. **Projektiranje sklopno – zaštitne opreme asinhronih motora maksimalne snage 200kW**, Arcelor Mittal Zenica, Department Aglomeracija, Februar. 2011 - Decembar 2011.;

Objavljeni radovi – reference

1. **M. Kokorus**, M. Muratovic, N. Hajdarhodzic, K. Balta, *Substation earthing system calculation*, CIGRE 11. Konferenca slovenskih elektroenergetikov, Laško, 2013;

2. **M. Kokorus**, V. Becirovic, M. Muratovic, N. Hajdarhodzic, M. Hrustic, *Harmonics analysis of compact fluorescent lamps current wave form and its influence on electrical energy quality*, 11. savjetovanje BH K CIGRE, Neum, 2013;

3. **M. Kokorus**, S. Delic, M. Muratovic, *Analysis of magnetic field arround the overhead transmission lines and possible solutions to mitigate their impact*, 11. savjetovanje BH K CIGRE, Neum, 2013;

4. **M. Kokorus**, M. Muratovic, N. Hajdarhodzic, K. Balta, *Substation earthing system calculation*, 11. savjetovanje BHK CIGRE, Neum, 2013;

5. **M. Kokorus**, K. Sokolija, *Solving Laplace differential equation using Markov chains in Monte Carlo method*, ICAT IEEE *XXIV International Conference on Information, Communication and Automation Technologies, Sarajevo, 2013;*

6. **M. Kokorus**, S. Delic, A. Mujezinovic, M. Muratovic, A. Carsimamovic, *Analysis of Possible Solutions for Reduction of Electrical and Magnetic Fields near 400 kV Overhead Transmission Lines*, Wessex Institute, 2nd International Conference on Environmental and Economic Impact on Sustainable Development, Ancona, 2014;

7. **M. Kokorus**, R. Gacanovic, K. Sokolija, M. Batalovic, H. Zildzo, *Super-Fast Algorithms for Solving Fields around Grounding Electrode Using Markov Chains - Monte Carlo Method*, ICHVE IEEE International Conference on High Voltage Engineering and Application, Poznan, 2014;

8. **M. Kokorus**, S. Delic, M. Muratovic, *Analysis of magnetic field around the overhead transmission lines and possible solutions to mitigate their impact*, Issue No. 8 Journal Bosanskohercegovačka elektrotehnika, ISSN 1512-5483;

9. **M. Kokorus**, A. Mujezinovic, *Computer Aided Design of the Substation Grounding System*, ICHVE IEEE International Conference on High Voltage Engineering and Application, Poznan 2014.

Ostale aktivnosti

- Član Bosanskohercegovačkog komiteta Međunarodnog vijeća za velike električne sisteme CIGRÉ od 2011.;
- Član Međunarodnog vijeća za velike električne sisteme CIGRÉ Paris od 2013.;
- Član Institute of Electrical and Electronics Engineers IEEE od 2013.;
- Član Aerokluba *Izet Kurtalić* Visoko od 2000. i sudionik državnih i federalnih takmičenja;
- Glavni sudija i organizator FAI (Fédération Aéronautiqe Internationale) Free Flight Word Cup (Svjetski kup) u Bosanskom Petrovcu, Bosna i Hercegovina od 2004. do danas;
- Oficijelni sudija na FAI World Championship in Free Flight World Cup (Svjetsko prvenstvo) Korenica, Hrvatska 2009.;
- Oficijelni sudija na FAI European Championship in Free Flight World Cup (Evropsko prvenstvo) Capannori, Italija, 2012.;
- Oficijelni sudija na FAI World Championship in Free Flight World Cup (Svjetsko prvenstvo) Moncotour, Francuska 2013.;

2. PREGLED STANJA U OBLASTI ISTRAŽIVANJA

Prema dostupnoj literaturi kandidatu na doktorskom studiju na Elektrotehničkom fakultetu u Sarajevu, Univerzitet u Sarajevu, dat je pregled stanja u oblasti istraživanja u kojoj je situirana doktorska disertacija. Pregled se sastoji od *sažetaka*, odnosno *abstracta* koji su na uobičajen način dati uz svaki rad, kako slijedi:

[1] Book deals with fundamental concepts and equations of power-system earth conduction, earth resistivity testing and analytical approximation of measured resistivities, the resistance of grounding arrangements, e.g. spherical grounds, plates and vertical ground rods, etc., the mutual impedance of insulted earth-return conductors, and propagation characteristics of earth-return conductors. Direct-current earth conduction and corrosion protection is amply described.

[2] The behavior of a grounding system under fault currents differs from its steady statebehavior. When the density of the injected current exceeds a critical value, then soil ionization phenomena occur, which decrease the soil resistivity and, consequently, the grounding impedance. The critical parameter for the ionization phenomenon is the soil critical electric field, which corresponds to the electric field threshold above which the soil ionization occurs. The aim of this paper is the experimental investigation of the soil ionization phenomenon on soil samples subjected to impulse voltages. The voltage and the current are recorded, and the soil critical electric field is calculated by using proposed in the bibliography methods. The influence of the soil parameters on the soil critical electric field is investigated.

[3] In this paper it is described general remarks on osmosis, an introduction to clay and so-called diffuse double layer theory, to a review of semi-permeability of clays, the relevant coupled processes and the corresponding coefficients. It isalso shown how non-equilibrium thermodynamics provides us with equations that are subsequently specified for the different processes, and which balance equations are relevant for our purposes. Some analytical solutions of this set of equations are presented for artificial but relevant example problems.Some properties of these solutions are investigated along with, for example, the infuence on osmotic pressure buildup of the choice of dependence of the reflectioncoeficent on concentration. The model equations are put to the test.

[4] U radu je prikazana primjena teorije prijenosnih vodova pri analizi utjecaja različitih parametara na dinamički odziv uzemljivača. Radi jednostavnosti izlaganja te interpretacije dobivenih rezultata, a bez gubitka općenitosti, za uzemljivač je odabrana vertikalno ukopana cijev. Uzemljivač je spojen sa zemljovodm u čiji je gornji kraj idealnim strujnim izvorom utisnuta struja. Promjenom dužine zemljovoda analiziran je utjecaj geometrije iznad tla na dinamički odziv uzemljivača. Idealni strujni izvor generira strujni impuls normiranog valnog oblika tzv. dvostruko eksponencijalnog impulsa. Promjenom parametara valnog oblika struje analiziran je utjecaj kosine (ili strmine) čela vala na dinamički odziv uzemljivača. U radu je analiziran i utjecaj parametara tla na dinamički odziv uzemljivača. Tlo je modelirano kao jednoslojni homogeni izotropni poluprostor. Granicatlo-zrak predstavljena je ravninom.

[5] The exact knowledge of the grounding system impedance,including its expected variability, is a matter of paramountimportance in the design of medium and high voltageinfrastructures. The principles underlining the physical processesinvolved in grounding are well established and so are theengineering concepts regarding safe operation of the groundedsystems. Quite a few theoretical expressions are widely used inthe project stage of any installation.Unfortunately, these expressions are only valid for simplegeometries and simplified material characteristics. Uncertaintyarise from the intrinsic complexity of the grounding environment: buried grids and rods, reinforced concrete foundationssurrounding them, weather dependent and non-uniform soilcharacteristics, etc. To overcome these limitations, in this paper the finite elementmethod is applied to obtain the grounding impedance and thepotential distribution around a real grounding system excitedwith sinusoidal currents at several frequencies.Additionally, for validating purposes, a single vertical ground rodhas been simulated and compared with the results obtained byother authors.FEM commercial software, in addition to some specific purposeuser functions, has been used.The method presented here can be applied to any realgeometry, electrode configuration and type of soil.

[6] This edition widely praised for its clarity, depth of explanation and extensive coverage, presents the fundamental principles of soil mechanics and illustrates how they are applied in practical situations. Worked examples throughout the book reinforce the explanations and a range of problems for the reader to solve provide further learning opportunities.

[7] Electromagnetic sensors such as ground penetrating radar and electromagnetic induction sensors are among the most widely used methods for the detection of buried land mines and unexploded ordnance. However, the performance of these sensors depends on the dielectric properties of the soil, which in turn are related to soil properties such as texture, bulk density, and water content. To predict the performance of electromagnetic sensors it is common to estimate the soil dielectric properties using models. However, the wide variety of available models, each with its own characteristics, makes it difficult to select the appropriate one for each occasion. In this paper it is presented an overview of the available methods, ranging from phenomenological Cole-Cole and Debye models to volume-based dielectric mixing models, and (semi-) empirical pedotransfer functions.

[8] A network consisting of a substation including its buried and aboveground components and its overhead transmission lines is analyzed using rigorous electromagnetic fields based analysis. The entire system is modeled and its performance during steady-state normal conditions and fault conditions is examined and discussed. A long section of a buried pipeline is also parallel to the transmission lines. The substation model includes buried and aboveground components such as ground conductors, transformers, cables, Gas Insulated Switchgears (GIS), bus bars and shielding structures in order to account for their impact on the overall network performance duringnormal and faulted conditions.

[9] Electrical Resistivity Tomography (ERT) is increasingly used to investigate moisture distribution in Municipal Waste Landfills, especially when leachate is injected in waste to enhance its biodegradation. It is proposed in this paper to theoretically assess the quality of ERT mapping, using COMSOL Multiphysics simulations of both hydrodynamical and geophysical aspects. Leachate injection is simulated using COMSOL's Porous Media and Subsurface Flow module which produces the effective saturation distribution. Virtual current injection following ERT principles is then performed on this variably saturated domain using COMSOL's AC/DC module, to produce the electric potential field and to derive the apparent resistivity distribution. The apparent resistivity data set is then inverted with a specific code to reconstruct a calculated resistivity model, which is finally compared to the initial field of effective saturation.

[10] The goal of paper is to calculate the response of an elementary groundingelectrode under high speed and high intensity current impulse. This consideration takes into account some nonlinear characteristic of the soil around the electrode. This paper presents the solution to this problem in the time domain by Finite Element Method using the COMSOL program. In this case the ionization phenomenon around the grounding electrode is taken into calculation through the function of varying the conductivity of every soil element vs. electric field intensity.

[11] This paper briefly exposed to the principles of modeling of soil ionization on thelightning rod grounding electrodes telecommunications systems and small power facilities. We also provide basic data on the computer model to simulate ION.GR ionization, which was created during the research project "Analysis of the frequency dependent parameters of the grounding." Using the above model we analyzed the variations of some important parameters on the effects of ionization on the short strap grounding electrodes. Particularly interesting appears the possibility of applying the analysis of this phenomenon in isolated and exposed to atmospheric discharge facilities.

[12] A novel method, which is based on electromagnetic field theory to calculate the current distribution in grounding grid is presented in this paper. The finite element method (FEM) is used to calculate the distribution of the fault current in the grounding grids. By using both the unidimensional units and the three-dimensional units in modeling the grounding grid and its surrounding soil, the performance of the real substation grounding grid can be analyzed. The current distribution in the grids as well as its distribution in the surrounding soil can be seen clearly. The accuracy of the calculation is improved significantly and both of the current flowing in the grids and the leakage current distributed in soil can be easily obtained under different condition.

[13] A circuit model with lumped time-variable parameter is proposed to calculate the transient characteristic of a grounding system under lightning current, which takes into consideration the dynamic and nonlinear effect of soil ionization around the ground electrode. The ionization phenomena in the soil are simulated by means of time-variable parameters under appropriate conditions. The infulences of soil parameters, location of feed point, and shape of the lightning impulse currend on the transient characteristic of grounding grids are discussed. The generated electromagnetic fields in substation are analyzed by using electrical dipole theory and image theory when the lightning current flows into the grounding system. The infulence of soil ionization on the electromagnetic fields is presented.

[14] This paper proposes a full-wave analysis to consider the influence of soil resistivity on the magnetic field inside buildings hit directly by a lightning strike. An electromagnetic theory approach based on the method of moments is used. This method allows for a transient analysis and accounts for the effects of soil resistivity. Calculations are performed in the frequency domain for a simplified case where the lightning channel is modeled assuming a constant current along the channel. The model is selected for ease of comparisons with the examples described in the IEC 62305-4 standard. A time domain numerical analysis is carried out to estimate the influence of soil resistivity on the radiated magnetic field. The effect of the soil resistivity on both the resultant and on the time derivative of the magnetic field is investigated for a 2 m mesh grid-like spatial shield of 10x10x10 m located in horizontally layered soil structures. Examples of transient resultant magnetic field induced by a typical positive stroke on a building represented as a grid like shield are presented, emphasizing the impact of soil resistivity. It is shown that the transient electromagnetic field is moderately affected by soil resistivity changes which, therefore, can be, in some cases, neglected in the computation process.

[15] The study on the physics of discharges in soil and performance of earthing networks subjected and obtain better electrical models of earthing systems. In this study, the characteristics of medium grain size sand ofdifferent moisture contents and impulse polarity are investigated. The soil characteristics of various moisturecontents under high impulse currents have been well studied in previous work. Until today, no publication has been made on the dry soil characteristics and no direct comparisons has been made between the characteristics of dry and wet soils under impulse conditions. This paper is therefore aimed to observe the characteristics of dry and wet soil under both impulse polarities. The results were discussed based on its voltage and current traces, impulse resistances and breakdown characteristics of the cylindrical test cell.

[16] Outdoor ac substations, either conventional or gas-insulated, are covered in this guide. Distribution, transmission, and generating plant substations are also included. With proper caution, the methods described herein are also applicable to indoor portions of such substations, or to sub-stations that are wholly indoors. No attempt is made to cover the grounding problems peculiar to dc substations. A quantitative analysis of the effects of lightning surges is also beyond the scope of this guide.

[17] and [18] Practical test methods and techniques are presented in this guides for measuring the electrical characteristics of grounding systems. Topics addressed include safety considerations, measuring earth resistivity, measuring the power system frequency resistance or impedance of the ground system to remote earth, measuring the transient or surge impedance of the ground system to remote earth, measuring step and touch voltages, verifying the integrity of the grounding system, reviewing common methods for performing ground testing, reviewing instrumentation characteristics and limitations, and reviewing various factors that can distort test measurements.

[19] A theoretical model for the analysis of groundingsystems located in soils with finitevolumes of arbitrary resistivities is presented. The boundary element method is used for the analysis. The procedures in the analysis are described in detail and the essential equations are presented. Analytical and numerical validations are also carried oust in the process. The results obtained using the new approach are in agreement with well-known simple case results and converge asymptotically to the uniform soil case. There is a wide range off practical groundingsystem scenarios which can be accurately modeled by using this new soil type. Examples showing several finitevolumesoil models are also presented in this paper.

[20] This paper describes solving of fields around grounding electrode using *Markov Chains – Monte Carlo* Method (MCMC). For systems with a very large number of elements and millions of equations which need to be solved, this method is often not applicable as it requires very long computation time. Therefore, it is necessary to improve existing algorithms and methods or develop new ones. The paper presents such attempt – development and application of *Conjugate Gradient Method* (*CGM*) mathematical model with *Compressed Row Storage* (*CRS*) format in solving fields around grounding electrode. For this, *MCMC* is used on two-dimensional model with set boundary conditions with the aim of rapid computation of very challenging problems. As an illustration of the proposed method possible application, calculations of thermal fields in the soil around grounding electrode during intensive wave of current are presented.

[21] This paper deals with design of the substation grounding system by using computer. As it is well known, proper design of the grounding system is most important part of the whole project of the substation, from safety point of view. Procedure of the measurement of the soil resistivity and interpretation of the measured results is given. Interpretation of the soil resistivity data and results of interpretation are explained. Also, calculation

procedure of potential distribution of the complex grounding system, grounding system resistance, distribution of touch and step voltage by using computer is presented. Whole procedure was implemented on the real substation grounding system. Results of the potential distribution on the ground surface of substation touch voltages and step voltages are calculated in the paper. Finally, analysis of the capacitors underground steel construction influence on all relevant parameters of the grounding system is given in this paper.

[22] In engineering practice CDEGS Software is the most commonly used program for earthing system calculation today. In order to get most accurate results in use with CDEGS, special care have to be taken in soil specific resistivity measurement at the substation location, which results will be used for determination of soil model parameters used in further calculation process. Measurements have to be done with Wenner 4 electrode method. When substation layout is confirmed, ten measurement profiles will be defined along which soil specific resistivity measurement will be done. Profiles will be defined to cover complete substation area. Taking care about substation crew safety, step and touch voltages values must be less than calculated maximum allowed for complete substation area. Paper presents analysis of numerical method calculation for 132/33/11kV earthing system, made using CDEGS software. Analysing process main goal is to determine all locations inside substation where step and touch voltages are not inside allowed ranges. For areas with exceeded touch or step voltages, actions are performed in order to satisfy defined safety limits criteria.

[23] Knjiga proučava fizičke i mehaničke osobine tla, tečenje vode kroz tlo, naprezanja i deformacije u tlu, parametre čvrstoće tla, nosivost tla, metode laboratorijskog i terenskog ispitivanja. Suvremena mehanika tla zasniva se na detaljnijim terenskim istraživanjima, složenijim laboratorijskim pokusima i primjeni raznih vrsta programa na osobnim računalima čime se bolje opisuje stvarno ponašanje tla, ali ne možemo reći da su svi problemi riješeni na odgovarajući način, pa istraživanja u ovom području i dalje intenzivno traju.

[24] Characteristics of soil ionization for different water contents, andthe parameters associated with the dynamic properties of a simple model grounding system subject tolightning impulse currents are presented. The laboratory experiments for this study were carried out based on factorsaffecting the soil resistivities. The soil resistivities are adjusted with water contents in the range from 2to 8% by weight. A test cell with a spherical electrode buried in the middle of the hemisphericalcontainer was used. As a result, the electric field intensity *E*c initiating ionization is decreased with thereduction of soil resistivities. Also, as the water content increased, the pre-ionization resistance *R*1 andthe post-ionization resistance *R*2 became lower with increasing current amplitude. The time-lag toionization t1 and the time-lag to the second current peak t2 at high applied voltages were significantlyshorter than those of low applied voltages. It was found that the soil ionization behaviors are highlydependent on the water content and the applied voltage amplitude.

[25] The aim of this paper is to calculate the response of grounding system under high-magnitude fault current accurately. In this work, A *FEM* model is presented to solve the problem in frequency domain. The ionized phenomenon in the soil around the grounding electrode is taken into account by setting the resistivity of every soil element varying with the electric field intensity. Open boundaries of earth are processed by introducing a spatial transformation which translates the semi-infinite space into the finite space. The suggested modeling is validated by comparison of the calculated results, which are laid out for grounding rod and grounding grid, with experimental and simulation results found in literatures.

[26] One of the important factors in designing an efficient lightning protection (LPS) system is to determine if a considered object, system or installation is exposed or not to electromagnetic interference. An exposed system or installation is vulnerable to unwanted sources of current and voltage including the most severe interference sources, which are lightning currents with wide range of statistical parameters. A reliable lightning protection system (LPS) requires installation of earth termination and effective bonding system. In design process of any kind of earthing system it is important to assure high quality of its components and stability of their performance and technical characteristics. Most important are here adequate mechanical strength of material used for electrodes, conductors and clamps and their high corrosion resistance in different type of environment determined by soil parameters and climatic conditions. Bonding refers to theelectrical interconnection of conductive parts designed to maintain a common electrical potential. Paper is addressed to characterization of fundamental requirements for LPS, given in new series of IEC 62305 and IEC 62561 (EN 50164) standards and presents the discussion on new required parameters and tests of lightning protection components related to requirements for conductors and earth electrodes, which are still under consideration within adequate maintenance teams and working groups of TC 81 IEC and CENELEC (CLC) TC 81X.

[27] The properties of sand withdifferent water contents were investigated under high-magnitude fast-impulse currents, and an equivalent circuit model for soil ionisation was derived. For the hemispherical test cell used, resistance values in the kilo-ohm range were obtained. These high valuesof resistance limited the current magnitudes to less than 300 A before breakdown occurred in the test cell. In practice, however, the resistance of an earth electrode is usually less than 10 and the transient current magnitudes can reach several tens of kiloamperes. It is, therefore, necessary to investigate the behavior of soils under high current magnitudes and compare it with low ac and dc test results. In order to achieve high impulse current magnitudes with the adopted test cell, low resistivity media were utilized as test soils. In this present paper, a new impulse test data using wet clay and sand mixed with controlled amounts of sodium chloride (NaCl) to obtain a range of low-resistivity materials, was analyzed. The characteristics of NaCl are also investigated under lowmagnitude low-frequency and high-magnitude impulse currents in order to understand better its effect on sand-salt soil mixtures. Impulse currents up to 5 kA were used during the test program. These new data would be useful in understanding the characteristics of a low earth resistance value (which is a typical condition at field site) under high impulse conditions. By including the nonlinear effect of the soil under high currents, more accurate modelling of protective devices and their performance could be achieved. In addition, the consideration of the nonlinearity in soils can help the optimum design of earthing systems.

[28] The effects of moisture contents is sand (1% to 10%), grain size (medium and fine), impulse polarity and earth electrode's dimension (hemispherical and parralel-plate test cell) on the threshold electric field. Ec value is obtained for low resistivity test media (resistive liquid medium, sand with large percentage of water content=15%, salt with different percentage of water content, and sand-salt soil mixtures). This paper is therefore to obtain the Ec value for these low resistivity test media. Using the avilable voltage and current traces, for the first time the Ec is taken when v-i curve starts to form a loop.

[29] This paper aims to extensively review, discuss, and compare the published studies on soil behavior under high currents, based on field tests, laboratory tests, and computational methods, conducted by previous authors from 1928 to 2003. The paper presents an informative review on soil electrical characteristics under high impulse currents as well as a useful list of references for researchers on nonlinear soil behavior.

[30] Overvoltage protective devices such as surge arresters and protective gaps are used to divert high lightning surges from line to earth through an earth electrode. An effective design of earthing systems is therefore important to dissipate fault current to earth effectively regardless of the type of fault. The characteristics of earthing systems at power frequency, low-voltage and lowcurrent magnitudes have been extensively researched and fairly well understood. However, the behaviour of earthing systems under transient conditions is still not fully clarified. Paper is to provide a better understanding of the characteristics of earthing systems under lightning impulse, as well as to present an informative review on previous work on soil ionisation phenomena under high impulse currents.

[31] i [32] U knjigama su opšta svojstva tla, tlo kao trofazni sistem, priroda i porijeklo mineralnog dijela tla, organska materija, humus i organizmi u tli, fizika tla i hemija tla. Zadatak fizike tla je da prouči osnovne osobine, čvrste, tečne i gasovite faze tla, njihovu dinamiku (vodno-zračni režim) i toplotne osobine tla koje su neophodne u izradi ove doktorske disertacije. Hemija tla izučava hemijska i fizičko-hemijska svojstva i procese u tlu, koji se odvijaju kako u prirodnim uslovima, tako i pod uticajem različitih aktivnosti od strane čovjeka.

[33] Fizičku pojavu upada strujnog impulsa u uzemljivač i rasprostiranja s njega karakterizira izražena međuzavisnost niza parametara-intenzitet struje (strujno polje), električno polje, specifični otpor (odnosno provodnost) tla, temperatura (toplotno polje), vlažnost (polje vlažnosti), kapilarno polje (osmoza), nehomogenost tla.

[34] U radu se predstavlja način proračuna elektromagnetskih prijelaznih pojava u sustavu *gromobranska instalacija-uzemljivač*. Gromobranska instalacija može biti sastavljena od gromobranskih užadi, vertikalnih štapova, dozemnih vodova, induktivnih grana, dok su uzemljivači sastavljeni od traka, užadi i vertikalnih štapova. Kompletan sustav razdvaja se na dva podsustava. Elektromagnetske prijelazne pojave analiziraju se posebno na svakom od podsustava, pri čemu se u svakom vremenskom koraku provodi odgovarajuće povezivanje uz korištenje Thevenenovih ekvivalenata. Uzimaju se u obzir frekventno ovisni parametri uzemljivačkog sustava.

[35] This paper describes methodology for the computation of the electromagnetic transients in the high voltage substations, taking into account transients on the substation grounding system. Simulation technology is based on the system decomposition. Interconnections between different subsystems are done in each time step using Thevenin equivalents. Frequency dependent impedance of grounding conductors is represented by the parallel combination of resistance-inductance branches, to enable simulation in the time domain. Lightning overvoltage computation is performed for one particular 123 kV high voltage substation.

[36] Field and laboratory measuraments have been made to determine the electrical conductivity, dielectric constant, and magnetic permeability of rock and soil in areas of interest in studies of electromagnetic pulse propagation. Conductivity is determined by makind field measuraments of apparent resistivity at very low frequencies, and interpreting the true resistivity of layers at various depths by curve-matching methods. Dielectric constant is estimated from field measuraments of water content and correlations of laboratory sample measuraments of parameters: water content and frequency.

[37] The efficiency of energy piles depends on their dimensions and the heat and moisture transfer characteristics of soils and pile materials. Conductive heat transfer in soil deposits is based on the solution of the Fourier equation with relevant initial and boundary conditions. The equation contains two parameters representing the thermal properties of material: the coefficient of thermal conductivity and the volumetric heat capacity. The results of an experimental study are presented first. Tests were conducted earlier to determine the heat and moisture transfer characteristics of a silty soil from the Mackenzie River Valley.COMSOL is used to simulate the heat and moisture transfer in two soil columns and the computational and experimental results are compared. Subsequently, the finite element analysis is extended to the analysis of an energy pile.

[38] U knjizi su opisani svi potrebni askpekti teorije elektromagnetskih polja i odgovarajućih metoda numeričkog modeliranja koje su potrebne za analizu raspodjele polja koja su u interesu ove doktorske disertacije.

[39] Article presents an interactive process of designing a large Grounding system. In this case applied the indirect boundary element method for solving the stationary electric field Grounding and used the computer program "Earth". In this work made a series of calculations allocation potential, touch voltage and step voltage on the ground, as per the given profile line. During postprocessing get the marked area within the substation where the voltage values exceeded permissible touch and step voltages, and is done interactively to add a grounding conductor. The result is an optimal variant of the Grounding system. It also performs the calculation of grounding the neutral zone is the distance from the Substation which will not impact current failure of telecommunications lines.

[40] U radu je prikazan model za proračun impulsnih impedancija složenih uzemljivača. Prikazani su rezultati proračuna impulsnih značajki uzemljivača tipične vangrdaske TS 110/10(20) kV. Utjecajne veličine varirane su u širokim granicama. Također je proveden proračun očekivanih lokalnih razlika impulsnih potencijala, uz uvažavanje stohastičkih parametara.

[41] Computer simulation has become an essential part of science and engineering. Digital analysis of components, in particular, is important when developing new products or optimizing designs. Today a broad spectrum of options for simulation is available; researchers use everythingfrom basic programming languages to various high-level packages implementingadvanced methods. Though each of these techniques has its own unique attributes.

3. MOTIVACIJA I CILJEVI ISTRAŽIVANJA

Uzemljivač je veoma važna komponenta elektroenergetskog sistema koja ima ulogu osiguranja zaštite života i zdravlja ljudi i životinja, kao i osiguranja tehničke funkcionalnosti sistema. To je mjesto rasprostiranja struje iz sistema u zemlju, bilo da se radi o struji groma, struji kvara ili radnoj struji. Stoga, pažljivo razmatranje kompleksnih pojava vezanih za uzemljenje, analiza bitnih proračunskih parametara, njihova promjenjivost, međuzavisnost, proračuni i dobro projektiranje uzemljenja, izvođenje, kontinuirano održavanje u skladu s propisima, garantiraju postignuće pravilne tehničke funkcije i sigurnosti živih bića od ozlijeđivanja i stradanja od električne struje. Priprema za projektiranje, proračun, te provjera dobivenih izlaznih i kontrolnih parametara elektroenergetskog sistema složen je i kompleksan posao s mnogo međuzavisnosti brojnih faktora i parametara.

U dosadašnjoj profesionalnoj karijeri radio sam na projektiranju električnih postrojenja, a posebno sam stekao visok stupanj iskustva u projektiranju uzemljenja i s njim povezanih proračuna u savremenim i moćnim programskim paketima. Iz navedenog, ova oblast mi je veoma privlačna za detaljnije proučavanje, posebno s aspekta nadgradnje i shvatanja mehanizma pojava koje do sada nisu uzimane u obzir pri projektiranju, a koje su od značaja i koje bi trebalo respektirati. Istraživanje pojava koje se zanemaruju pri projektiranju i proračunima uzemljenja odgonetnulo bi da li se one s pravom zanemaruju. Ukoliko bi se pokazalo da je to zaista tako, mnogo života i skupocjene opreme bi se moglo sačuvati i spasiti na vrijeme.

Ponašanje uzemljivača pri upadu strujnih valova velikog intenziteta i dugog trajanja, kao npr. stalna struja kratkog spoja predmet je zanimanja u ovom istraživanju. Tu se podrazumijeva i odgonetanje složenih međudjelovanja poljā u tlu oko uzemljivača, te njihov utjecaj na parametre tla. Dakle, tokom rasprostiranja injektirane struje s uzemljivača odvija se zamršena fizička pojava koju određuju brojni stalni i nestalni parametri i njihove međuzavisnosti. Mehanizam odvijanja te pojave dosad je pojednostavljivan iz više razloga. Glavni razlog je bio komplicirani matematski proračun povezan s matričnim računanjem, neraspolaganje s podacima brojnih fizičkih parametara, nepoznavanje relacija zavisnosti i međuzavisnosti tih parametara i drugo. Fizičku pojavu upada struje u uzemljivač i rasprostiranja s njega karakterizira izražena međuzavisnost niza parametara: intenzitet struje (strujno polje), električno polje, specifični otpor (odnosno provodnost) tla, temperatura (toplotno polje), vlažnost (polje vlažnosti), kapilarno polje (osmoza), (ne)homogenost tla i drugo. Npr. ako u zemlju teče struja značajne jačine u dužem vremenu, proizvedena toplina u tlu oko uzemljivačke elektrode uzrokovat će porast temperature u tom tlu. Pod određenim okolnostima to zagrijavanje uzrokuje isparavanje vlage u tom tlu, isparenje vlage uzrokuje povećanje specifičnog električnog otpora tla, to povećava gubitke, koji povećavaju temperaturu (toplotu), koja nadalje isušuje tlo, ... Takvo nestabilno stanje izaziva *spiralu loma*, što može rezultirati veoma visokim vrijednostima otpora rasprostiranja, nedopustivo velikim vrijednostima napona uzemljivača, te napona dodira i koraka što dalje može ugroziti živa bića i opremu. Upravo zato, u središtu interesa jeste istraživanje ponašanja poljā koja se pojavljuju u tlu oko uzemljivača i njihove međuzavisnosti, te refleksije na glavne proračunske parametre uzemljenja.

4. METODOLOGIJA I PLAN ISTRAŽIVANJA

U središtu interesa ovog rada jeste istraživanje ponašanja raznorodnih poljā koja se pojavljuju u tlu oko pobuđenog uzemljivača, njihove međuzavisnosti i refleksije na glavne parametre uzemljenja. Za alanirana istraživanja tokom izrade doktorske disertacije osnovu će činiti:

- Analiza pojave i ponašanje poljā: strujno polje, toplinsko polje, polje vlage, specifični otpor tla, kapilarno polje (osmoza), (ne)homogenost tla kao i eventualno druga polja koja budu od interesa u ovom istraživanju;
- Utjecaj navedenih poljā na parametre projektiranja uzemljivača, realizaciju, ponašanje u pogonu, kontrolu i mjerenje;
- Teorijsku postavku i uspostavu matematskog modela za proračun poljā;
- Uspostavljanje aplikativnog računarskog modela u kojem će biti moguća simulacija pojave injektiranja struje u uzemljivač i rasprostiranja sa uzemljivača u okolno tlo s uzimanjem u obzir (signifikantne) međuzavisnosti navedenih raznorodnih poljā;
- Utjecaj navedenih poljā na proračun specifičnog otpora tla, čije će se istraživanje bazirati na eksperimentalnoj ravni.

Odgovarajuća ispitivanja fizičkih i hemijskih osobina tla, kao što su sadržaj vlage, soli, granulacija i drugo, uzetog s lokacije realne trafostanice, bit će ispitivana u laboratoriji koja posjeduje uređaje, instrumente i opremu za takva istraživanja. Na realnom električnom postrojenju, s kojeg budu uzeti uzorci tla, bit će vršeni proračuni opasnih potencijala, te uticaj fizičkih i hemijskih osobina tla na njih kao i njihov međusobni utjecaj.

Rezultati eksperimentalnog istraživanja imaju kvantitavni karakter i njihove vrijednosti daju precizniji uvid u fizičko-hemijska svojstva tla, predstavljaju važan faktor pri klasifikaciji tla koje je neophodne za ovo istraživanje. Laboratorijska istraživanja bi trebala biti koncipirana na slijedeći način:

- Odrediti cilj koji se treba postići laboratorijskim istraživanjem;
- Odrediti kriterije;
- Potreban pribor za laboratorijsko istraživanje;
- Postupak koji se primjenjuje pri izvođenju analize;
- Analiza i način obrade i prezentiranja rezultata;
- Zaključak.

Prije samog početka istraživanja bit će potrebno izvršiti radnje u cilju pripreme uzorka tla u poremećenom stanju radi daljnjeg izvođenja analiza. Priprema uzorka će se sastojati u slijedećim radnjama: sušenje uzorka koje traje od jednog do nekoliko dana, gdje će u vremenskim intervalima biti mjerene veličine od interesa ove doktorske disertacije; sitnjenje uzorka i prosijavanje, te utjecaj tih promjena na navedene veličine.

Upravo na osnovi tog istraživanja, te koristeći se zakonitostima fizike, elektrotehnike i matematike, na temelju principa *uzrok-posljedica*, definirat će se načela međuzavisnosti poljā u tlu oko uzemljivača, te na osnovi tog će bit uspostavljen odgovarajući model.

Model, čiji će ulazni podaci biti dobiveni eksperimentalnim putem, treba omogućiti da se na jednostavan način mogu iskušavati – oponašati i analizirati pojave kad se struja s uzemljivača rasprostire u okolno tlo.

Kao kruna istraživanja, planira se uspostava modela, koji će moći vjerodostojno simulirati zamršenu pojavu – kroz uzimanje u obzir međuzavisnosti navedenih raznorodnih poljā, a jedan od rezultata simulacije očekuju se izlazni dijagrami ovisnosti ključnih proračunskih parametara uzemljenja, kao npr. parametri tla i procentualnog udjela vlage u tlu, kao i dijagrami ovisnosti ključnih parametara tla i temperature tla.

5. OČEKIVANI ZNANSTVENI DOPRINOS DISERTACIJE

Postignuća doktorske disertacije, kao koristiv doprinos, trebaju biti primjenjiva u praksi za (pr)ocjenu parametara pravilnog projektiranja električnih postrojenja i samog uzemljenja s aspekta uzimanja u obzir kompleksnog mehanizma međuzavisnosti poljā u tlu oko uzemljivača.

Kao osnovni znanstveni doprinos očekuje se uspostava originalnog modela ponašanja pojedinih poljā u tlu oko pobuđenog uzemljivača, kao npr. – električno polje, strujno polje, toplotno polje, polje vlage, kapilarno polje (osmoza), ..., te refleksija promjena, zavisnosti i međuzavisnosti tih poljā na ključne proračunske parametre uzemljivača – specifični električni otpor tla ρ (odnosno specifičnu električnu provodnost σ), permitivnost ε, permeabilnost μ, .
Očekuje se praktična i efikasna primjenjivost predloženog modela u smislu vjerodostojnijeg simuliranja pojava na uzemljivaču i u tlu oko uzemljivača iz čega će biti moguće s boljom tačnošću ekstrahirati glavne parametre za analizu, proračun, projektiranje, realizaciju i kontrolu ponašanja u pogonu uzemljenja visokonaponskih električnih postrojenja. To će se pokušati pokazati iskušavanjem predloženog modela varijacijom ulaznih veličina s ciljem dobivanja odraza tih promjena na izlazne - bitne aspekte pojave kao što je:

- Utjecaj promjene i međuzavisnosti raznorodnih poljā na sigurnosne aspekte uzemljenja u okviru granica postrojenja, kao i aspekata sigurnosti izvan postrojenja – u javnom prostoru;
- Uspostava bilateralne međuzavisnosti pojedinih parova poljā, njihove sukcesivne sekvencijalne - lančane zavisnosti;
- Uspostava modela kompleksnog mehanizma promjene ključnih parametara tla kao što su: specifični otpor tla ρ, permitivnost ε i permeabilnost μ.

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