# *Actual Stage of the Research Regarding the AC Interferences on Common Corridors*

Marius PURCAR, Calin MUNTEANU, Vasile TOPA,
Laura GRINDEI and Adina RACASAN

***Abstract:*** *The paper outlines the most important steps of the research development in the field of the electromagnetic AC interference between high voltage overhead power lines and pipelines sharing the same corridor. In the first part of the paper the most important conclusions of the international literature survey concerning the relevant methods and approached are outlined. In the second part of the paper the most significant interference coupling mechanism are emphasized. In the last part of the paper, a brief description of the nowadays available software packages is done. Final conclusions of the study performed end the paper.*

***Keywords****: AC interference, OHL power lines, pipelines*

## 1. INTRODUCTION

Sharing of common corridors by gas pipelines and overhead power transmission lines is becoming quite common. As the electrical energy can be transferred from power transmission lines to pipelines through inductive, conductive and capacitive coupling, when a power transmission line runs in parallel with a pipeline for a considerable length, important induced AC voltages may appear on the pipeline.

Stray currents due to these induced voltages can cause corrosion of metallic structures although the amount of metal loss is less than an equivalent amount of DC current discharge would produce. The magnitude of AC stray current is often large – hundreds of amperes under electromagnetic induction and thousands of amperes during power line faults which can lead to shock hazard for personnel and can damage the structure and related equipment.

The international regulation practices like NACE International Recommended Practice RP0177, “Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems” [1], potentials in excess of 15 volts should be considered hazardous and steps should be taken to reduce the hazardous potential level.

## 2. REVIEW OF THE METHODS ANT TECHNIQUES TO APPROACH THE AC INTERFERENCE ANALYSIS

A significant number of papers and research studies have been published both on the mechanisms and modeling of the AC induced voltages and their mitigation in the pipelines. An overview of these researches developed so far is presented below.

The initial attempts to study the AC interferences are based on the widely known Carson's formulae [2]. Carson and Pollaczek described in [3] inductive coupling between parallel conductors in the presence of a half space conductive medium (earth). Sunde [4] extended Carson's work towards multilayer earth and conductors near point sources of current. Later, Pohl [5] included the electrical characteristics of the pipelines like resistance to earth of a coated bitumen pipeline surface. He demonstrated that electrical discharges can occur on the whole surface area of bitumen coated pipelines for relatively low voltages (1000 - 1200 V) concluding that resistance to earth reduces drastically with increasing voltage.

In a study of buried mitigation wires using electrical models Favez et. al. [7] suggested that bonding the mitigation wire to the pipeline via spark gaps would increase efficiency of the mitigation.

Taflove and Dabkowski [8] predicted the induced voltages on gas transmission pipelines by a 60 Hz AC power transmission line sharing a joint right-of-way using electrical transmission line theory. Later on they performed field tests on a buried, 34-inch diameter gas pipeline adjacent to a 525 kV AC power transmission line for 54 miles [9] and made comparison between measured and inductive coupling and predictions designed in [8].

Induced voltages on buried irrigation pipeline were examined by Jaffa and Stewart [10], based on the theory described in the Electric Power Research Institute (EPRI) report [6] to a specific case of a buried irrigation pipeline running parallel to a distribution circuit. Authors showed that under unbalanced operating conditions, dangerous voltages can occur at one end of the pipeline.

Manuscript received December 6, 2009. The work was supported by Romanian Ministry of Education, Research and Innovation, under the ID_2539 Research Project

Dawalibi et. al. [11] designed a computer based analysis to ensure personnel safety and pipeline integrity during power system faults occurring near the Trans Quebec and Maritimes gas pipeline. The studies were based on methods described in [6] to determine the location and magnitude of induced AC voltage peaks. The maximum coating stress voltage occurring during fault, was in the order of 2500 volts.

P. Kouteynikoff made in [12] an international survey of different national regulations with respect to exposure between metal pipelines and high voltage (HV) power structures (overhead or underground lines, substations etc.). This survey underlined the lack of standardization and not all countries attach equal importance to this type of exposure. Only twelve countries reported official "rules of good practice".

Jacquet et. al. [13] presented the possible effects of earth potential rise of towers during faults as well as corrosion problems that may be caused by induced voltage resulting from the normal operation of high voltage transmission lines.

Dawalibi and Southey [14] described a computational tool software package, ECCAPP (Electromagnetic and Conductive Coupling Analysis from Powerlines to Pipelines), which resulted from the EPRI/A.G.A. research program [15]. The method presented indented to be comprehensive and aimed to solve all possible cases of inductive as well as conductive coupling to multiple buried pipelines. However, the number of segments required modeling the pipeline being usually very large made impossible the use of this software. That becomes even prohibitive, if that approach was used for transient analysis. Later Dawalibi and Southey presented in [16] a set of design curves illustrating the effects of various parameters upon conductive and inductive interactions between transmission lines and pipelines. The parametric analysis indicates that buried mitigation wires can be very effective, resulting in up to 65% reductions in peak pipeline potentials during fault.

Sobral et. al. used in [17] the Decoupled Method [18, 19] to simplify the calculation of the interferences affecting a single communication circuit or a single pipeline, caused by a short - circuit occurring along a single nearby transmission. The also highlighted both the magnetic and the resistive couplings existing between the transmission lines and the communication circuit or pipeline.

Abdel-Salam et al. [20] developed a method based on Charge Simulation Method (CSM) for calculating the induced voltages on fence wires/pipelines underneath AC power transmission lines. The calculated induced voltages compare favorably with those measured experimentally.

Southey et al. [22] demonstrated using computer simulation software described in [11, 14, and 15], the performance of a new highly effective AC interference mitigation method. The method, which combines the effectiveness of grounding conductors and gradient control wires, attenuated both inductive and conductive interference providing cathodic protection as well.

Yang and Xu [23] used a Fourier series technique to calculate the magnetic field produced by buried cables, due to an additional steel pipe nearby. An iterative procedure is employed to handle the non-linear characteristics of the steel pipe and to determine the varying permeability in it.

Satsios et al. [24] investigated the two dimensional, quasi stationary, electromagnetic field of a faulted power transmission line in the presence of a buried pipeline, of mitigation wires and of a multi-layer ground. The related diffusion equation has been numerically solved by using the Finite Element Method (FEM). Using FEM results and Faraday's law, magnetic vector potential, as well as the voltages induced across the buried pipeline and remote earth, are calculated. Parametric analysis has shown that there is a significant influence of the depth and resistivity of the first ground layer, of the resistivities of the different ground layers and of the configuration of mitigation wires on the electromagnetic field and on the voltages induced across the buried pipeline and remote earth. Later Satsios et al. addressed in [25] the influence of inhomogeneous earth on the electromagnetic field considering the eddy currents induced in all conductive parts, i.e. in overhead ground wires, mitigation wires, buried pipeline and earth layers.

Djogo and Salama [26] proposed a method for calculation of currents and voltages in the system of parallel pipelines and buried conductors. The method is based on the lousy transmission line model for buried conductors and the previous methods based on the same approach were modified by abandoning the Thevenin circuit representation of pipeline sections and by deriving a 4-pole equivalent ¼ circuit of a pipeline section. A generalized matrix 4-pole equivalent circuit is derived for a system of parallel buried conductors as well, by using the modal method. A general case of buried conductors not parallel to the power line is also derived.

Dawalibi et. al. [27] examined the mechanism of electromagnetic interference caused by a power system substation, including a portion of its incoming and outgoing transmission lines on a neighboring pipeline. Two approaches, a circuit approach and field approach, are used to carry out the study. The maximum difference between the two approaches is less than 15% for the cases studied which involve a parallel pipeline exposure. They also discussed the levels of the touch and step voltages for a few typical right-of-way systems under loaded and faulted conditions. The effects of a typical mitigation system on the inductive interference levels are also studied.

Christoforidis et. al. presented in [28] an improved hybrid method, employing finite element method along with Faraday's law and standard circuit analysis, in order to predict the induced voltages and currents on a pipeline with defects on its coating, running parallel to a faulted line and remote earth.

Collet et. al. [29] presented observations and experiments carried out on site and in the laboratory(1993-1996) that lead to the definition of certain relevant parameters concerning AC corrosion risks for Gaz de France..

Southey et. al. [30] tried to state the mitigation requirements for pipelines installed in the high voltage AC corridors. He solved later [31] a even more difficult problem of estimating what mitigation is required to maintain pipeline coating stress voltage within acceptable limits during fault conditions on power systems.

Kouloumbi *et. al.* [32] checked the effectiveness of cathodic protection through in situ long term monitoring and analysis of pipeline electrical parameters. The results gave an insight into the cathodic protection system operation, caused by AC interference.

Elhirbawy *et. al.* presented in [33] the calculation and analysis of the electromagnetic fields established by currents in power transmission lines, particularly by those in single-phase-to-earth fault condition based on the Finite Difference Method (FDM). They described a physical example for evaluation of the electromagnetic field coupling between a power transmission line and a pipeline buried in the body of the earth. This work focuses on developing FDM procedures to solve for the electromagnetic field derived from Maxwell's equations applicable to the region in the air, on the earth plane, and in the body of the earth.

Christoforidis discussed in [34] a hybrid method employing finite element calculations along with Faradays law and standard circuit analysis. The method is used in order to calculate the induced voltages and currents on a pipeline with defects, running in parallel to a faulted line and remote earth. Non-parallel exposures are converted to parallel ones and dealt with similarly. The defects are modeled as resistances, called leakage resistances. The fault is assumed to be outside the zone of influence as well as a single line to ground one such that conductive interference is negligible. A sample case is analyzed and discussed. The results show that although the pipeline defects act in a way as to reduce the levels of induced voltages and currents, large currents can flow to earth through the defects that may damage the pipeline. In [35] Christoforidis et. al. presented a new hybrid method employing finite element calculations and standard circuit analysis that may be used in order to calculate the induced voltages and currents on a pipeline running parallel to a faulted line. Nonparallel exposures are converted to parallel ones and dealt with similarly. Later on, Christoforidis et al. analyzed in [36] the influence of a soil structure composed of layers with different resistivities, both horizontally and vertically, on the inductive part of the interference. The method used to determine the inductive interference consisted of finite element calculations and standard circuit analysis. The results demonstrated that a good knowledge of the soil structure is necessary in order to estimate the above interference with minimum error.

Bortels et. al. [37] developed simulation software tool for predictive and mitigation techniques for pipeline networks influenced by high-voltage (HV) power lines. The software can deal with any configuration (no limitation on the number of pipes, transmission lines, bonds, groundings, coating, and soil resistivity) and is very user friendly and robust since a general applicable algorithm is used to calculate the induced electromagnetic force (EMF), eliminating the need for a subdivision of the pipelines in sections parallel or not to the transmission line(s). With the calculated values for the EMF, the induced voltages and currents are then obtained by solving the well known transmission- line model using a numerical technique that allows to specify the pipeline parameters (diameter, coating, soil resistivity, etc.) for each individual section of the pipeline.

## 3. INTERFERENCE COUPLING MECHANISMS

Typical electromagnetic field of a HV transmission line, source of induced voltages, is shown in figure 1. The electric and magnetic fields created by a transmission line induce charges and currents in neighboring metallic objects. The electrical influence depends on the electrical characteristics and the geometry of the neighboring system (e.g. pipeline) severity of the effect being directly related to the electrically continuous length of the pipeline that runs parallel to the power line and how well the pipeline is insulated.

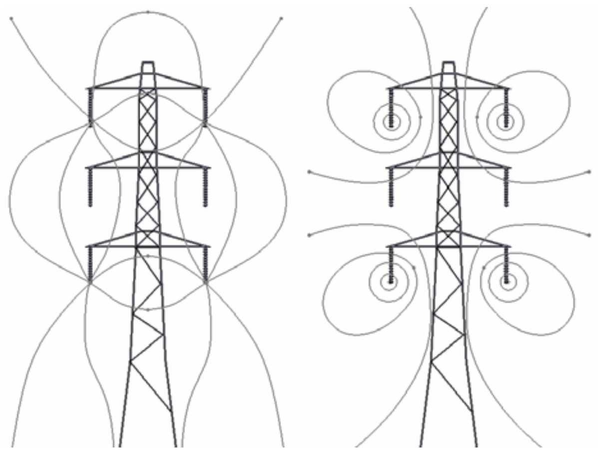

**Fig. 1.** Electric (left) and magnetic (right) field produced by a OHL power line.

There are three basic methods by which AC currents and voltages can be induced on metallic structures near AC power lines. The first one is electrostatic coupling where the structure acts as one side of a capacitor with respect to ground. This is only of concern when the structure is above grade. Secondly, electromagnetic induction may occur when the structure is either above or below ground. In this case, the structure acts as the single-turn secondary of an aircore transformer in which the overhead power line is the primary. Finally, resistive coupling is caused by fault currents from AC power towers that flow on and off the underground structure.

### 3.1. Capacitive Coupling

Electric field of the high voltage transmission line generates the capacitive coupling by inducing electric charges in the neighboring metallic structures. This represents a form of capacitive coupling operating across the capacitance between the AC transmission lines and the pipeline, in series with the capacitance between the pipeline and the adjacent earth as shown in figure 2.

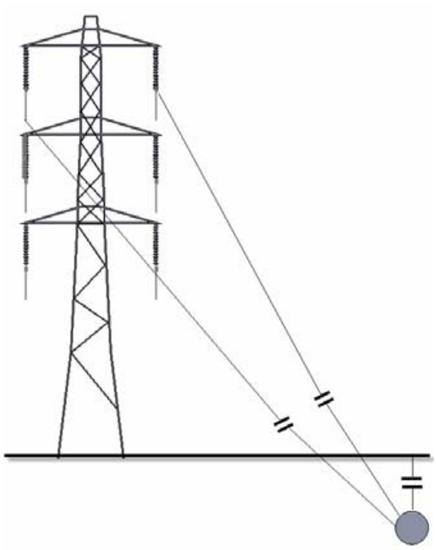

**Fig. 2.** Capacitive coupling.

As long as the capacitance between the pipeline and earth is negligible a potential is not normally induced on a buried pipeline, even when dielectric bonded coatings are used. However, during installation, a voltage can be produced by the influence of a strong electrical field on an insulated pipe when being lifted up from the ground and carried around using a crane. In some cases, the voltage can be above the maximum safe voltage limit for a pipe. In normal situations, contacting the pipe will only result in a slight electrical shock and the pipe voltage is immediately reduced to zero.

Some parameters that influence the capacitive coupling are given below.

- Capacitive coupling is directly proportional with the transmission line voltage;
- Capacitive influence is inverse proportional with lateral distance between the transmission line and the pipeline.
- Phase arrangements have an important influence on the capacitive coupling.

### 3.2. Inductive coupling

Inductive effects are the most important of all the three couplings. The inductive interference is the result of the magnetic field (see figure 3) generated by the power line.

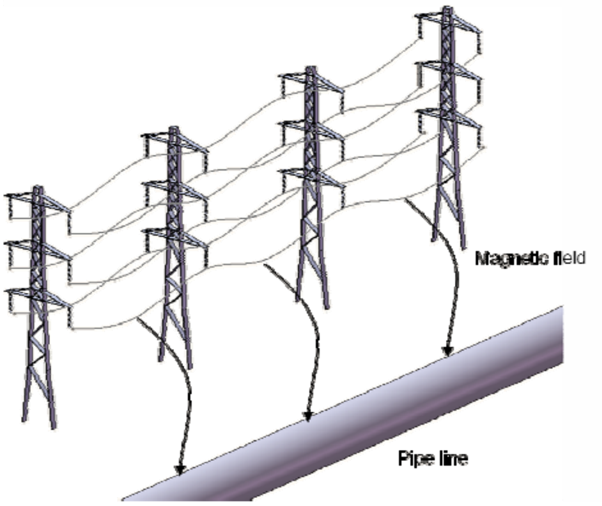


**Fig. 3.** Inductive coupling.

Neighboring pipelines running parallel to or in close proximity to transmission lines or cables are subjected to induced voltages caused by the time-varying magnetic fields produced by the transmission line currents. In case of a three phase system, if all the three phase wires are at equal distances from the axis of the pipeline, voltage induced on the pipeline will be zero. In practice this case is seldom met, as most of the time, the asymmetry between the three phase conductors and the pipeline causes the induction of non-zero voltage in the pipeline. The inductive influence problem is severest in the case of faults. The induced electromotive forces (EMF) cause currents circulation on the pipeline and voltages between the pipeline and the surrounding earth. In the normal operating conditions, the balance of the three phase currents causes no substantial effect. In this case, voltage induced is low, due to the geometrical asymmetry of the pipeline from power line. However under faulted conditions, high voltages and currents may be induced in the nearby pipeline, which may result in shock hazards to people or working personnel touching the pipeline or other metallic structures connected to it.

### 3.3. Conductive Coupling

When a ground fault occurs in an installation (substation, power plant, tower etc.) the current flowing through the grounding electrode produces a potential rise of the electrode and the neighboring soil with respect to a remote grounding bed. Conductive coupling occurs between the electrical installation and a nearby pipeline if the pipeline is directly connected to the ground electrode of the HV system (i.e. inside a power station) or if the pipeline enters the “Zone of influence" of electrical installation. A high difference of potential can then appear across the coating of the pipeline due to the local earth potential rise. In practice,

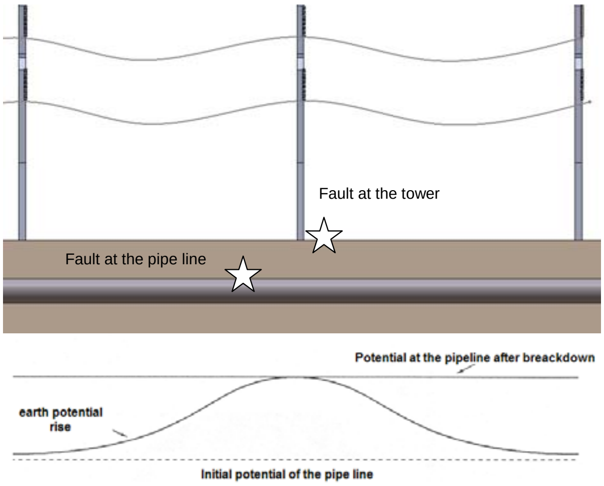


**Fig. 4.** Conductive coupling.

conductive coupling most often results from the second case.

## 4. SOFTWARE PACKAGES

By taking into account the researches conducted in the field of the AC induced voltages and their mitigation on buried pipelines by high voltage electric power transmission line is not surprising that there is an industrial need for user-friendly simulation software able to predict and mitigating these phenomena. A brief description of the existing software is given below.

ECCAPP calculates electromagnetic and conductive coupling effects between transmission lines and nearby pipelines. Software package developed jointly for EPRI and AGA (American Gas Association). It combines a n input data preprocessor with a computation algorithm which evaluates the effects of both conductive and inductive interference for arbitrarily positioned above-ground and buried conductors which could occur in typical rights-of-way. Computer Program ECCAPP analyzes the effects of power transmission lines on neighboring gas pipelines and determines the influence of mitigation measures, if any, on interference levels. The software is based on the transmission line method [11] and later on merged into Right-Of-Way package [39].

Right-Of-Way is designed by SES Technologies [38]. Right-Of-Way models arrangements of buried and aerial conductors. The software is able to compute currents and voltages resulted on the modeled utility including conductors associated with the power line, for normal (load) and fault conditions. It analyses simple and multi-component conductors, including bare or coated pipes and pipe-enclosed cable systems buried in soil. This computer program is able to analyze the combined effects of inductive (electromagnetic) and conductive (galvanic, through earth) coupling. These effects may develop simultaneously during power faults at transmission lines structures which are near gas pipelines, or during normal conditions.

CatPro is a software designed by Elsyca [40]. It has especially been developed to design and study the cathodic protection of a network of pipelines protected by sacrificial or impressed current/voltage anodes. Effects of stray currents leaking from DC-traction systems can easily be taken into account, allowing a quick and profound study of train positions, power station voltages and drainage currents on the overall protection level. CatPro allows a very flexible selection of pipes, anodes and tracks into your project and allows you to activate/deactivate the external connections that link them with one single mouse click.

## 5. CONCLUSIONS

A lot of efforts have been paid along the years for the development of accurate computation models of the OHL power lines induced currents and voltages on the neighbor pipelines sharing the same corridor. Based on the developed mathematical models and computation techniques, several software packages are available nowadays. However, to our knowledge, all of the available computer programs limit the modeling capabilities to parallel or near parallel geometries such as the ECCAPP [6] and Right-of-Way program. This limitation to pseudo-parallel geometries requires a subdivision of the pipeline(s) in a number of sections that are more or less parallel to the transmission line, which seriously reduces flexibility and can lead to important errors if the distances vary strongly along the influence zone. In addition, most of the available programs are restricted in the number of pipelines, transmission lines and (direct) bonds that can be modeled. This is a serious restriction since in many corridors a large number of pipelines are bonded together, e.g. for cathodic protection purposes.

## ACKNOWLEDGMENTS

Authors are gratefully to the Romanian Ministry of Education, Research and Innovation, for the support within the frame of the ID_2539 Research Project.

## REFERENCES

1. NACE Standard Recommended Practice SP0177-2007, "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems", 2007.
2. J.R. Carson, "Wave Propagation in Overhead Wires with Ground Return", *Bell System Technical Journal*, Vol. 5, pp 539-554, 1926.
3. F. Pollaczek, "On the Field Produced by an Infinitely Long Wire Carrying Alternating Current", *Electrische Nachricten Technik*, Vol. III, 1029, No. 9, pp. 339-359, 1926.
4. E. Sunde, "Earth Conduction Effects in Transmission Systems", *Van Nostrand Company*, New York, 1949.
5. J. Pohl, "Influence of High-Voltage Over-Head Lines on Covered Pipelines", CIGRE, Paper No. 326, 1966.
6. "Mutual Design Considerations for Overhead AC Transmission Line and Gas Transmission Pipelines", EPRI/A.G.A. Project 742-1, EL 904/PR-132-80, 1978.
7. B. Favez, J.C. Gougeuil, "Contribution to Studies on Problems Resulting from the Proximity of Overhead Lines with Underground Metal Pipelines", *CIGRE Proceedings*, Paper No. 336, 1966.
8. Allen Taflove, John Dabkowski, "Prediction Method for Buried Pipeline Voltages due to 60 Hz AC Inductive Coupling Part I –

Analysis" *IEEE Transactions on Power Apparatus and Systems*, Vol. 98, No. 3, pp 780-787, 1979.
9. John Dabkowski, Allen Taflove, "Prediction Method for Buried Pipeline voltages Due to 60 Hz AC Inductive Coupling Part II – Field Test Verification" *IEEE Transactions on Power Apparatus and Systems*, Vol. 98, No. 3, pp 788-794, 1979.
10. Jaffa K.C., Stewart J.B., "Magnetic Field Induction from Overhead Transmission and Distribution Power Lines on Buried Irrigation Pipelines", *IEEE Transactions on Power Apparatus and Systems*, Vol. 100, No.3, pp 1039-1048, 1981.
11. F. Dawalibi, A. Pinho, "Computerized Analysis of Power Systems and Pipelines Proximity Effects", *IEEE Transactions on Power Delivery*, Vol. 1, No. 2, pp 40-48, 1986.
12. P. Kouteynikoff, "Results of an International Survey of the Rules Limiting nterference Coupled into Metallic Pipelines by High Voltage Power Systems ", *ELECTRA*, pp 55-66, paper no. 110, 1987.
13. Jacquet, W.B.R. Moore, "Effects of Earth Currents on Burried Pipelines and Cables", *CIGRE Proceedings*, Vol II, Paper No. 36-06, 1988.
14. F.P. Dawalibi, R.D. Southey, "Analysis of Electrical Interference From Power Lines To Gas Pipelines Part I: Computation Methods", *IEEE Transactions on Power Delivery*, Vol. 4, No. 3, pp 1840-1846, 1989.
15. "Power Line Fault Current Coupling to Nearby Natural Gas Pipelines", EPRI/A.G.A. Project 742. EL-5472/PR176-510, November 1987.
16. F.P. Dawalibi, R.D. Southey, "Analysis of Electrical Interference from Power Lines to Gas Pipelines Part II: Parametric Analysis", *IEEE Transactions on Power Delivery*, Vol. 5, No. 1, pp 415-421, 1990.
17. S.T. Sobral, W. Castinheiras, V.S. Costa, D. Mukhedkar, "Interference Between Faulted Power Circuits and Communication Circuits or Pipelines – Simplification using the Decoupled Method ", *IEEE Transactions on Power Delivery*, Vol. 6, No. 4, pp 1599-1606, 1991.
18. S.T. Sobral, V.G.P. Fleury, J.R. Villalba, D. Mukhedkar, "Decoupled Method for Studying Large Interconnected Ground System Using Microcomputers – Part I – Fundamentals", *IEEE Transaction on Power Delivery*, Vol. 3, No. 4, pp. 1536-1544, 1988.
19. S.T. Sobral, V.G.P. Fleury, J.R. Villalba, D. Mukhedkar, "Decoupled Method for Studying Large Interconnected Ground System Using Microcomputers – Part II – Utilization on the Itaipu Ground System and complementary Aspects", *IEEE Transaction on Power Delivery*, Vol. 3, No. 4, pp. 1545-1552, 1988.
20. Mazen Abdel-Salam, Abdallah Al-Shehri, "Induced Voltages on Fence Wires and Pipelines by AC Power Transmission Lines", *IEEE Transactions on Industry Applications*, Vol. 30, No. 2, pp 341-349, 1994.
21. F. Dawalibi, N. Barbeito, "Measurements and Computations of the Performance of Grounding Systems Buried in Multilayer Soils", *IEEE Transactions on Power Delivery*, Vol. 6, No. 4,pp 1483-1490, 1991.
22. R.D. Southey, F.P. Dawalibi, "Recent Advances in the Mitigation of AC Voltages Occuring in the Pipelines Located Close To Electric Transmission Lines", *IEEE Transactions on Power Delivery*, Vol. 9, No. 2, pp 1090-1097, 1994.
23. Xiao-Mei Yang, Xiao-Bang Xu, "Interference of Nonlinear Ferromagnetic Pipeline on Magnetic Field Produced by Powerlines", *IEEE Transactions on Power Delivery*, Vol. 11, No. 2, pp 644-649, 1996.
24. K. J. Satsios, D. P. Labridis, P. S. Dokopoulos, "The Influence of Multi Layer Ground on the Electromagnetic Field of an Overhead Power Transmission Line in the Presence of Buried Conductors", *Archiv fur Elektrotechnik*, Vol. 80, No. 5, pp 343 – 348, 1997.
25. K.J. Satsios, D.P. Labridis, P.S. Dokopoulos, "Finite Element Computation of Field and Eddy Currents of a System Consisting of a Power Transmission Line above Conductors Buried in Nonhomogenous Earth" *IEEE Transactions on Power Delivery*, Vol. 13, No. 3, pp 876-882, 1998.
26. G. Djogo, M.M.A. Salama, "Calculation of Inductive Coupling From Power Lines to Multiple Pipelines and Buried Conductors", *Electric Power Systems Research*, Vol 41, pp 75-84, 1997.
27. F.P. Dawalibi, Y. Li, J. Ma, "Safety of Pipelines in Close Proximity to Electric Transmission Lines", *Proceedings of 2000 IEEE IAS Workshop on Electrical Safety in Industry*, New Delhi, pp 15-20, April 14-15, 2000.
28. Georgios C. Christoforidis, Petros S. Dokopoulos, Kostas E. Psannis, "Induced Voltages and Currents on Gas Pipelines with Imperfect Coatings Due to Faults in a Nearby Transmission Line", *Proceedings of IEEE Porto Power Tech Conference*, pp 401-406, September 2001.
29. Erwan Collet, Bernard Delores, Michel Gabillard, Isabelle Ragault, "Corrosion due to AC Influence of Very High Voltage Power Lines on Polyethylene-Coated Steel Pipelines Evaluation of Risks-Preventive Measures", *Emerald Journal*, Vol. 48, No. 4, pp 221-226, 2001.
30. R.D. Southey, W. Ruan, F.P. Dawalibi, "AC Mitigation Requirements: A Parametric Analysis", Corrosion/2001 *Proceedings of NACE International Conference*, Texas, March 11-16, 2001.
31. R.D. Southey, W. Ruan, F.P. Dawalibi, S. Fortin, "Estimating AC Mitigation Requirements for Pipelines Installed in High Voltage AC Corridors: Fault Conditions", available at www.sestech.com/pdf/163NACE%202003%20Paper%20-%20Fault%20Mitigation%20Parametric%20Analysis.pdf".
32. N. Kouloumbi, G. Batis, N. Kioupis, P. Asteridis, "Study of the Effect of AC Interference on the Cathodic Protection of a Gas Pipeline", *Emerald Journal*, Vol. 49, No. 5, pp 335-345, 2002.
33. M.A. Elhirbawy, L.S. Jennings, S.M. AI Dhalaan, W.W.L. Keerthipala, "Practical Results and Finite Difference Method to Analyze the Electric and Magnetic Field Coupling Between Power Transmission Line and Pipeline", *Proceedings of the 2003 International Symposium on Circuits and Systems*, ISCAS '03, pp 431-434, 2003.
34. G.C. Christoforidis, "Inductive Interference Calculation on Imperfect Coated Pipelines Due to Nearby Faulted Parallel Transmission Lines", Electrical Power System Research, Vol. 66, pp 139-148, 2003.
35. Georgios C. Christoforidis, Dimitris P. Labridis, Petros S. Dokopoulos, "A Hybrid Method for Calculating the Inductive Interference Caused by Faulted Power Lines to Nearby Buried Pipelines", *IEEE Transactions on Power Deliver*y, Vol. 20, No. 2, pp 1465-1473, 2005.
36. Georgios C. Christoforidis, Dimitris P. Labridis, Petros S. Dokopoulos, "Inductive Interference on Pipelines Buried in Multilayer Soil Due to Magnetic Fields From Nearby Faulted Power Lines", *IEEE Transactions on Electromagnetic Compatibility*, Vol. 47, No. 2, pp 254-262, 2005.
37. Leslie Bortels, Johan Deconinck, Calin Munteanu, Vasile Topa, "A General Applicable Model for AC Predictive and Mitigation Techniques for Pipeline Networks In°uenced by HV Power Lines", *IEEE Transactions on Power Delivery*, Vol 21, No. 1, pp 210-217, 2006.
38. Ahmed A .Hossam-Eldin, Wael Mokhtar, "Interference Between HV Transmission Line and Nearby Pipelines", *Proceedings of the 12th International Middle-East Power System Conference 2008, MEPCON 2008*, pp. 218-223, March, 2008
39. www.sestech.com
40. www.elsyca.com

Lect. Dr.eng. Marius PURCAR
Prof. Dr.eng. Calin MUNTEANU
Prof. Dr.eng. Vasile TOPA
Assoc.Prof. Dr.eng. Laura GRINDEI
As. eng. Adina RACASAN

Department of Electrotechnics
Technical University of Cluj-Napoca
Baritiu 26-28,
RO-400027, Cluj-Napoca, ROMANIA
Tel. +40 264 401 244
Fax. +40 264 592903
E-mail: Marius.Purcar@et.utcluj.ro