Budapest University of Technology and Economics
Faculty of Electrical Engineering and Informatics

PREVENTIVE LIGHTNING PROTECTION AND LIVE WORKING FOR INCREASING SAFETY OF WORKS ON ELECTRICITY GRID

THESIS SUMMARY

BÁLINT NÉMETH

THESIS ADVISOR:

ISTVÁN BERTA PHD.

PROFESSOR

BUDAPEST, 2014.

1 INTRODUCTION

Protecting ourselves against lightning strikes is one of the major challenges in the history of mankind. We have been trying to protect human life and man-made structures against the destructive effects of lightning strikes ever since the beginning of human culture. It is hardly surprising that lightning appears in all the mythologies, religions, branches of art and science. The fear and dread of this natural phenomenon is well explained by its visible and audible effects and the enormous destruction eventually caused by it.

Protection against fire, explosion and loss of human life by developing means of so-called primary lightning protection has usually increased the level of safety. Nowadays, protection against the secondary effects of lightning strikes is becoming a more important issue. These effects, propagated by conduction and induction, endanger the operation of our systems of telecommunication and information technology, which have by now become of paramount importance, since our everyday life and industrial activity is highly relying on these systems. Our life has become almost unimaginable without the continuous and reliable operation of them.

The basis of design of traditional lightning protection solutions is determined by establishing the level of acceptable risk. In case of some special objects, the amount of expected damage in case of a lightning strike can vary by orders of magnitude depending on the initial status of the object before the strike. Protection systems however ensure a constant level of protection, which can in certain cases limit the primary use of the protected object or largely increase the cost of the protection solution.

In some special cases, installing traditional primary and secondary protection systems would incur unacceptably high costs or constitute a technically insolvable task. In these cases, preventive lightning protection methods, together with several other recent developments and results of the field, can be excellently used in order to increase the level of safety while keeping costs at an acceptable level.

2 SUMMARY OF THE DISSERTATION

Continuing the 70 years of tradition of lightning protection research in Budapest (BME VET High Voltage Group), we have presented the preventive lightning protection system at the International Conference on Lightning Protection (ICLP) in 2006 in Japan. Preventive lightning protection means an augmentation of traditional protection systems against the primary and secondary effects based on a novel approach of avoiding and/or alleviating lightning strike damages by introducing certain preventive protection measures if and only if a thunderstorm cell approaches the protected object (e.g. building, tower, industrial site) within a dangerous distance and keeping the measures in force only until the risk of lightning strike exists. To determine the time and spatial extent of danger we are using data from the lightning monitoring systems that have been established and are being operated worldwide, also in Hungary.

In this dissertation I am dealing with preventive lightning protection as a new method in order to extend the usage of the original concept and determine the factors that make the utilization of the method especially advantageous. Studies are focused on high voltage power lines, with special attention to a rapidly developing and spreading concept, live line maintenance work.

In the first part of the dissertation, I give a summary of existing systems of lightning monitoring, forecasting and local detection. This is followed by case studies showing examples where traditional lightning protection can not be installed economically.

I give a detailed description of my new concept, extended preventive lightning protection, which incorporates several tools, methods and technologies, and offers most advantages in case of objects which have a risk level that changes dynamically both versus time and in space. The possible uses of the new method are also assessed by means of a risk management algorithm.

I give a description of my own development, a fuzzy-based Decision Support System for experts, which is aimed to optimize the protection solution taking into account both technical and economical parameters. I analyze the rulebase of knowledge-based fuzzy logic systems and assess the level of reliability they offer; furthermore I evaluate the results of trial runs conducted with real input data.

Based on a critical analysis of Hungarian and international codes for the conduct of work on power lines, I point out the deficiencies found, and as a solution suggest the use of the preventive lightning protection method in order to increase safety of activities on power lines.

After summarizing the advantages of live-line works, I assess the sources of risk both in case of live line work and working on earthed lines and conclude the criteria for the safe conduct of work.

3 RESEARCH METHODOLOGY, RESOURCES AND PUBLICATION OF RESULTS

For the development and testing of the preventive lightning protection system, computations and simulations have been run and applied to practical cases. My development, the decision support system is based on fuzzy logic.

During my work I have established a live line work laboratory for educational, research, practice and demonstration purposes on the premises of the High Voltage Laboratory of the Budapest University of Technology and Economics, and with the considerable aid of companies of the industry. The established 400 kV practice equipment has largely contributed to being able to analyze and conduct research on the equipment and technological procedures used for live line work, especially in case of the high voltage measurements conducted on the electrostatic protective clothing used.

Based on the computations, simulations and measurements, I have formulated four theses. Contents of the theses were published at international and Hungarian conferences (ICLP, ICAE, ISEI, ISH, ICOLIM) and in professional periodicals (Elektrotechnika, Journal of Physics, Journal of Electrostatics).

4 THESES

Thesis 1:

The new method developed by the lightning protection research group in Budapest, known as preventive lightning protection, consisting of reducing the risk of damage with a considerably lower cost by applying protection measures for only a pre-determined period of time, has been further developed in order to make combined use of tools, procedures and technologies. I have found that the technical and economical advantages of preventive lightning protection can be exploited mostly when used for protecting objects that have a time-varying risk level. [Németh et al. 2006], [Gulyás, Németh et al. 2007], [Gulyás, Németh et al. 2007b], [Németh et al. 2007a], [Németh et al. 2007d], [Gellén et al. 2011], [Németh B. 2014a]

In certain cases, the classic primary and secondary lightning protection solutions (a system consisting of lightning rods, conducting wires and grounding rods, or a zonal, coordinated overvoltage protection system) can not be applied or would not constitute an economically viable option. Costs associated with improving efficiency of lightning protection systems are increasing exceptionally rapidly.

The primary and secondary lightning protection devices are usually parts of the protected structure, however they are only necessary for rare and short periods of time, while a thunderstorm cell is in the immediate vicinity of the protected object. Apart from this issue, there are problems with the spatial distribution as well. Protection zones are defined in a static manner, in the conventional approach both the number and the extent of the zones is excessive, while circumstances are changing dynamically. These considerations support the concept that the risks associated with a lightning strike should be reduced by different, preventive measures. Having assessed the function and typical operation of different protected structures, I have defined the group of objects having a time- and space-varying risk level. For example, a stadium can often be empty, while at times tens of thousands of people fill the rows of seats; at an airport, aircraft are sometimes parked empty on the apron, while at other times they are filled with passengers or are conducting dangerous operations such as refueling; most of the times there is no-one on top of a transmitter station in several hundred meters height, but from time to time, maintenance works are being conducted by a group of mechanics carrying expensive equipment and sensitive instruments. I have concluded and proved the fact that the advantages of preventive lightning protection methods are most marked when used to protect such objects with a variable risk level.

I have extended the definition of preventive lightning protection such that it includes the combined use of tools, procedures and technologies. According to this new concept, the first step of the process is a professional analysis of the task. The analysis shall result in several scenarios, emergency plans each corresponding to different levels of protection. Each of these shall include the set of conditions, timeframe, costs and the expected level of protection associated with them. A decision body (consisting of an individual or a committee) shall be set up, which will be continuously informed about the location of thunderstorms and the condition of the protected object. This body shall continuously evaluate the situation and make decisions accordingly. The protection tools and measures to be used will be chosen based on the actual situation: possible measures may include applying temporary or portable protection systems (e.g. rocket or laser-based lightning protection), procedures aimed for protecting the population of the area (such as making churches, public buildings and other well protected structures open for public), applying technological procedures protecting equipment and workers or suspending the operation of certain, particularly endangered technological processes (stopping rocket launch, protecting sensitive equipment). Decisions shall be made based on the comparison of all the costs incurred by the application of different emergency plans and the amount of eventual damages, taking into account the probability of damage as a function of the situation changing in time and space, aiming for choosing the optimum decision out of the available possibilities.

I have formulated the concept that the decision body shall apply protection devices, preventive measures and technologies only immediately before the danger of lightning strike occurs, and shall order to suspend all these measures immediately when the situation has ceased to be dangerous. This concept can be effectively used only if a sufficient set of emergency scenarios is available to the decision body, data concerning thunderstorm cells in the area are continuously received, and based on these, the body is able to make immediate decisions in order to protect only the endangered parts of the area and only for the necessary period of time.

According to the lightning protection standard MSZ EN 62305, if the protection solution suggested in the standard can not guarantee an acceptably low level of estimated risk in a particular case, further measures are recommended to reduce hazards. In such cases, preventive measures can be taken to reduce risk below the accepted level. I have developed a risk management algorithm that aids the unambiguous classification of different situations, the identification, evaluation and reduction of risks. The concept of this process fits well that of the standard MSZ EN 62305, therefore I am suggesting the amendment of the standard to include the above algorithm. Designers of objects shall be able to decide whether applying preventive lightning protection measures is necessary in the particular case or not, having followed the above described steps of the procedure.

Thesis 2:

A new decision-support system has been developed, which is based on possible measures, forecasts and alarms, incorporates fuzzy logic, and although is relying on the zonal procedure of preventive lightning protection, however is capable of producing a more accurate forecast than that of the zonal procedure even in case of unreliable and continuously changing input parameters, while also determining the start and end time of preventive measures. [Kiss, Németh et al. 2007], [Németh et al. 2008b], [Gulyás, Németh et al. 2008], [Németh et al. 2009], [Gulyás et al. 2010], [Gulyás et al. 2011], [Gulyás et al. 2012], [Németh B. 2014a]

The trajectory of thunderstorm cells is usually not unambiguously predictable; however it is also not completely stochastic. A qualified human observer, having followed the past trajectory of a cell, is able to make general assumptions on the expected future motion. The developed soft-computing based system supports this prediction by a module applying fuzzy computation methods. The advantage of fuzzy systems in this case is that it is capable of rapidly drawing conclusions based on the appropriate rule-base processing a large amount of – even incomplete and noisy – input data.

I have developed a measure-based expert system. Input parameters of the system are supplied by local and global thunder-monitoring and radar systems. Input data are fed to the fuzzy deducing model through a data pre-processing module. The pre-processing module also utilizes database data concerning the protected area and object(s). This database also supplies the parameters of different preventive measures to the fuzzy deducing model.

In the system, thunder data are processed with the fuzzy evaluation method, the result of which will support the decision whether issuing an alarm is necessary in case of a thunderstorm cell approaching the protected object to a certain distance. This way of processing data enables us to differentiate between thunderstorms based on their trajectory due to the fact that the decision support system does not only compare the actual distance of the thunderstorm cell from the protected object to a single preset value, but also takes into account the velocity and direction of movement of the cell. Based on this model, an estimate is given for the time when a warning shall be issued and withdrawn. The model takes into account the influencing environmental and ergonomic factors of carrying out the protection measures and determines the optimum time for initiating it.

I have also evaluated the reliability of the decision support system. After developing the details of the model and the fuzzy evaluating system, trial data and real-time data have been used for test runs evaluating the operation of the systems.

Thesis 3:

Based on Hungarian and international standards and regulations, works on high voltage power lines can only be performed when the weather, visibility and other environmental conditions are suitable. I have recognized and proved the fact that the presently used model of such works is not appropriate for the case of a thunderstorm cell approaching a protected object with large linear extent such as an overhead power line. For these cases I have redefined the conditions for interrupting and eventually resuming works in a way that ensures the level of safety required. [Handl et al. 2005], [Németh et al. 2005a], [Németh et al. 2007b], [Németh et al. 2007c], [Németh et al. 2007d] [Németh et al. 2008a], [Németh B. 2014b], [Kiss, Németh et al. 2014]

Hungarian and international standards prescribe the measures to be taken in case of unfavorable weather conditions. These constraints are based on the reduction of insulation capacity, visibility or the ability of free movement of the worker. In case of open-air works, the following limiting circumstances have to be taken into account: precipitation, dense fog, thunderstorms, strong winds, salt storm and extreme low temperature. In general, it is difficult to exactly quantify the limits associated with the environmental circumstances of such works in a way that they give valid limitations for all cases. Therefore, to correctly assess these circumstances, good decision-making qualities, forethought and experience is required from the leader and all participants of works.

I have recognized that unambiguous procedures (immediate suspension of works in progress) can be set up only for the following cases: thunderstorm occurring within sight or audible range and precipitation at the site. However, standards, Hungarian and international regulations are not entirely definite even in these cases. One of the characteristics of high voltage overhead lines – in comparison with most protected objects such as a building, a single tower, industrial site, etc. – is their large linear extent. The track of a power line of up to several hundreds of kilometers length often crosses hilly terrain, forests or ridges, in almost all cases way out of sight. It can not be expected that the leader (the person responsible for the safe conduct) of works perceives a thunderstorm passing over or near the same power line, but up to 100 km from the site of works, and comes to an appropriate decision.

Both the detailed theoretical background and experience show that overvoltages can occur on high-voltage power lines for several reasons. One of the typical reasons for such dangerous overvoltages can be a lightning striking the conductors, the shield wire, one of the towers or even the ground in the immediate vicinity of the line. Due to the complexity of technology and the large distances, anticipation is of great importance in case of works on the high voltage networks: the persons conducting works shall be warned about an approaching thunderstorm early enough so they can move to a safe site before they would actually be endangered by a lightning strike.

I have recognized that currently used lightning protection measures do not ensure sufficient safety for the workers in all cases.

The required level of safety can, however, be reached by using the decision support feature of the preventive lightning protection concept. This protection is able to issue a warning in due time, as appropriate for the type of work, thus, works can be suspended and immediately resumed when necessary.

Thesis 4:

I have analyzed the sources of risks of works on high voltage power lines both for the cases of live line works and works on earthed lines. I have proved that the overvoltages occurring due to a lightning strike can possibly lead to accidents, injuries even if all val-

id prescribed technological procedures for works on earthed lines are complied with. In comparison, accidents caused by lightning strike can be avoided with greater safety in case of conducting works on the live line with the appropriate technology. [Kimpián et al. 2009], [Németh 2003], [Németh 2004], [Németh et al. 2005b], [Németh et al. 2011], [Tamus et al. 2011], [Németh et al. 2012a], [Németh et al. 2012b], [Németh et al. 2012c], [Göcsei, Németh B et al. 2012], [Göcsei, Németh B. 2013a], [Göcsei, Németh B et al. 2013b], [Göcsei, Németh B. 2014a], [Göcsei, Németh B et al. 2014b], [Kiss, Németh et al. 2014]

Based on critical analysis and international experience it can definitely be seen that live line work technology is spreading even in spite of its requirements for highly educated and disciplined workforce and considerable investment to ensure their safety. This is explained by the economical advantages offered by introducing the technology. Based on a detailed analysis of experience on live line works, it can be said that the technology offers both directly quantifiable savings and non-quantifiable advantages related to unplanned events on the transmission network.

I have analyzed in detail the possible sources of risk and the prescribed procedures aimed to avoid accidents due to these risks (e.g. allowed proximity to lines: electrical and ergonomic point of view, minimum insulation distance). The most severe risk is associated with eventual overvoltages both in case of works on earthed and live lines. However, the regulations of works on earthed lines do not ensure a sufficient level of protection against atmospheric overvoltages (reference is made to recent accidents on high voltage lines both in Hungary and abroad). On the contrary, the design of the technology for works on live lines takes into account the objects at undefined potential, the effect of the tools used on the insulation distance, and certain techniques apply overvoltage-limiting measures on site. Problems caused by atmospheric or switching overvoltages can be handled by the combined use of electrostatic protective clothing and technological elements designed with a sufficient safety margin. The risk of accidents can be considerably reduced by strictly adhering to the procedures of the technology. When live line works are in progress, the 'special state of operation' (disabling or changing the settings of protection and automatic reclosure devices) always has to be enabled as an added protection against a serious error.

I have formulated the fact that in case of live line works, the persons conducting the works are prepared for the presence of voltage, i.e. working on a potential other than that of ground. On the contrary, when working on an earthed line, either an atmospheric overvoltage or one arising due to a switching, or inductive/capacitive coupling can lead to an accident (for example, when working on one circuit of a double circuit line, earthed at each endpoint but not at the working site, a lightning striking the operating circuit can possibly induce such a voltage in the circuit connected to ground at the endpoints that the arising shockwave can result in an electric shock hitting the workers).

5 PRACTICAL USE OF THE PREVENTIVE LIGHTNING PROTECTION SYSTEM

Development of the preventive lightning protection system was initiated due to unfortunate accidents both in Hungary and abroad. The use of the extended preventive lightning protection (PLP) system is currently being introduced on the Hungarian transmission network (MAVIR ZRt. - OVIT ZRt.). Based on the demo version of the experts system, several other partners (e.g. TERNA, KEPCO, E.ON) have expressed their interest in using the system.

The preventive lightning protection system is connected on-line to the Hungarian lightning monitoring system, therefore thunderstorm activity can be traced on the entire area of the country. The system also continuously receives and updates information on the schedule of works on the power lines and accesses the database containing the geographical coordinates of the power line towers.

The primary aim of the preventive lightning protection system is to support the safe conduct of maintenance and other works on the power lines of the transmission system. The system is operated through the web, utilizing a client-server architecture, and incorporates an own database. During operation, it communicates with several partner systems to gather the necessary information, which is then processed, converted to the appropriate format and stored in the own database of the system.

Two of the partner systems providing data for the preventive lightning protection system are:

- MAVIR HLIB[1],
- MAVIR Spectrum.

Input of the preventive system in these cases is the disconnection, reconnection and earthing of power lines of the transmission network. Data are transferred to the PLP through standard communication channels. The data of a disconnection are transferred to the PLP where the record for the work is generated and scheduled based on HLIB data (including description of the line and work, planned time of commencing and finishing works, type of work, hourly breakdown of works when possible, name and phone number of responsible person). On the day of works, Spectrum (SCADA system of Hungarian TSO) forwards the change in the status of the ground isolator switches at each endpoint of the line. If the line is earthed at both endpoints with the earthing blade of the line disconnector, the given work is considered to be commenced and the respective PLP alarming system is activated.

On the index page of the lightning protection system, the user encounters an embedded Google map showing the territory of Hungary, with the location of any thunderstorm cells being over the country overlaid on the map. If, based on the calculation of the system, a thunderstorm is expected to approach an area where works on a power line are in progress, the system notifies the person responsible for the work (and any other persons involved, predetermined by MAVIR) by means of an automated telephone call 30, 20 and 10 minutes before the critical time, calling him and the workers upon suspending works and leaving the working area. This voice-based warning is more reliable and effective than SMS, e-mail or other electronic forms of notification.

[1] HLIB: Network Disconnection Request Filing System: a system for planning and registration of scheduled works and other disconnections on the transmission system and parts of the distribution system

6 PUBLICATIONS OF THE AUTHOR DIRECTLY RELATED TO THE TOPICS OF THE THESES

Total: 35

[Gellén et al. 2011] GELLÉN T. B., SZEDENIK N., KISS I., **NÉMETH B.**, *On the Problems Regarding the Risk Calculation Used in IEC 62305,* Journal of Physics (Institute of Physics), Electrostatics 2011, Conf. Ser. 301 pp. 1-5. Paper 012065

[Göcsei, Németh et al. 2012] GÖCSEI G., **NÉMETH B**., TAMUS Z. A., KISS I.: *Face Protection Investigation Against Electric Field On Live Line Workers*, 2012 IEEE International Symposium of Electrical Insulation, San Juan, Amerikai Egyesült Államok, 2012. 06. 10 - 2012. 06. 13. IEEE, pp. 535-539. ISBN: 978-1-4673-0486-3

[Göcsei, Németh B. 2013a] GÖCSEI G., **NÉMETH B**.: *Comparison of conductive clothing's effectiveness*, 4th International Youth Conference on Energy 2013. Siófok, Magyarország, 2013. 06. 06 - 2013. 06. 08

[Göcsei, Németh et al. 2013b], GÖCSEI G., **NÉMETH B.,** KISS I., TAMUS Z. Á.: *Shielding efficiency of conductive clothing in magnetic field*., JOURNAL OF ELECTROSTATICS 71:(3) pp. 392-395. (2013)

[Gulyás, Németh et al. 2007] GULYÁS A., **NÉMETH B**., KISS I.: *Importance of Forecasting in Preventive Lightning Protection,* 13th International Conference on Atmospheric Electricity, Peking (China), 13-17. 08. 2007

[Gulyás, Németh et al. 2007b] GULYÁS A., **NÉMETH B.**, KISS I., BERTA I.: „*Planning and Evaluation of Preventive Lightning Protection*" 17th EMD, Bialystok; September 19-21, 2007

[Gulyás, Németh et al. 2008] GULYÁS A., **NÉMETH B.**, KISS I., BERTA I.: *Theoretical framework of preventive lightning protection* 29th International Conference on Lightning Protection, Uppsala (Sweden), 23-26. 06. 2008

[Gulyás et al. 2010] GULYÁS A., MAKELA J., **NÉMETH B.**, V. COORAY, KISS I., BERTA I.: *Local detectors in preventive lightning protection*, 30th International Conference on Lightning Protection, 2010, Cagliari, Italy

[Gulyás et al. 2011] GULYÁS A., MAKELA J., **NÉMETH B.**, V. COORAY, KISS I., BERTA I.: *Local detectors in preventive lightning protection*, Journal of Lightning Research (published by Bentham Science Publishers), pp 139-148, 2012.07.13., DOI: 10.2174/1652803401204010139

[Gulyás et al. 2012] GULYÁS A., KISS I., **NÉMETH B**. Berta I.: *Issues of risk in non-permanent lightning protection methods,* 31st International Conference on Lightning Protection. Vienna, Ausztria, 2012. 09. 02 - 2012. 09. 07. Paper 232.

[Handl et al. 2005a] HANDL P., **NÉMETH B.,**: *Villámcsapások hatásai a kompakt távvezetékre,* Elektrotechnika, 3, 9/2005

[Kimpián et al. 2009] KIMPIÁN A., **NÉMETH B.,** BERTA I.: *Construction, Operation and Maintenance of the Hungarian 750, 400 and 220 kV Grid among Open Market Environment, Incorporating Live Working into a Variety of Maintenance and Troubleshooting Methods*, CITTES 2009, 22-24. 04. 2009, Buenos Aires (Argentina),

[Kiss, Németh et al. 2007] KISS I., **NÉMETH B.,** SZEDENIK N., GULYÁS A., BERTA I.: *Advanced risk analysis of systems endangered by ESD,* Journal of Physics (Institute of Physics), Electrostatics 2007, 2007. 03. 25-29, Oxford, UK 2008 J. Phys.: Conf. Ser. 142 012033 (4pp) doi: 10.1088/1742-6596/142/1/012033

[Németh 2003] NÉMETH B.: *Távvezetéki zárlatra vezető folyamatok elemzése a magyar villamos átviteli hálózat három éves zárlati statisztikájára alapozva,* 2003 október, BME Tudományos Diákköri Konferencia

[Németh 2004] NÉMETH B.: *Nagy villamosenergiarendszer-üzemzavarokra vezető főbb folyamatok elemzése*, Elektrotechnika Journal, 7-8/2004, pp.: 207-209

[Németh et al. 2005a] NÉMETH B., GULYÁS A.: *How to Use Lightning Detection in the Examination of Power Line Faults?* The 3rd International Scientific Symposium ELEKTROENERGETIKA 2005, Stará Lesná (Slovakia), 21-23. 09. 2005, ISBN 80-8073-305-8

[Németh et al. 2005b] NÉMETH B., GULYÁS A., BERTA I.: *New Preventive Methods in the Lightning Protection of Power Lines and Systems*, PSC 2005 International Scientific Conference, Timisoara, Romania, 3-4. 11. 2005, ISSN 1582-7194,

[Németh et al. 2006] NÉMETH B., GULYÁS A., SZONDA S., BERTA I.: *Application of Preventive Measures in Lightning Protection*, 28th International Conference on Lightning Protection, Kanazawa, Japan, 18-22. 09. 2006,

[Németh et al. 2007a] NÉMETH B., GULYÁS A., KISS I., BERTA I.: *Efficiency of lightning detection systems in preventive lightning protection*, International Youth Conference On Energetics 2007, Budapest, 30. 05-01. 06. 2007

[Németh et al. 2007b] NÉMETH B., GULYÁS A., BERTA I.: *Increasing Safety in Live Line Maintenance Applying Preventive Lightning Protection,* 13th International Conference on Atmospheric Electricity, Peking, China, 13-17. 08. 2007,

[Németh et al. 2007c] NÉMETH B., GULYÁS A., KISS I., BERTA I.: *Practical Use of Preventive Lightning Protection*, 15th International Symposium on High Voltage Engineering, Ljubljana, Slovenia, 27-31. 08. 2007.

[Németh et al. 2007d] NÉMETH B., KISS I., BERTA I.: *The cost effective lightning protection for live line workers*, 9th International Conference on Live Maintenance, Torun, Poland, 4-6. 06. 2007.

[Németh et al. 2008a] NÉMETH B., KISS I., BERTA I.: *Preventive lightning protection for live line workers*, IEEE International Symposium on Electrical Insulation, Vancouver, Canada, 8-11. 06. 2008.

[Németh et al. 2008b] NÉMETH B., KISS I., BERTA I.: *Lightning protection of open air mass performances*, 29th International Conference on Lightning Protection, 23-26. 06. 2008, Uppsala, Sweden

[Németh et al. 2009] NÉMETH B., KISS I.: *Application of fuzzy logic based expert system in preventive lightning protection,* 11th International Conference on Electrostatics 2009, JOURNAL OF ELECTROSTATICS, Volume 67, Issues 2-3, May 2009, pp. 477-481

[Németh et al. 2011] B. NÉMETH, A. KIMPIÁN, I. BERTA, J. MEIXNER, *Dr. Béla Csikós LLM Education Center in Hungary*, 10th ICOLIM, 31.05.-02. 06. 2011, Zagreb, Croatia

[Tamus et al. 2011] TAMUS Z. Á., **NÉMETH B.,** KIMPIÁN A., KISS I., BERTA I.: *Examination of time-varying magnetic fields exposure of live line workers,* 17th ISH, 22-26. 08. 2011, Hannover, Germany, pp. 1-5. Paper G-033.

[Németh et al. 2012a] NÉMETH B., GÖCSEI G., KISS I., TAMUS Z. Á.: *Vezetőképes öltözetek villamos paramétereinek vizsgálata*, ELEKTROTECHNIKA 105:(10) pp. 15-19. (2012)

[Németh et al. 2012b] NÉMETH B., GÖCSEI G., TARCSA D.: Extra low frequency electric and magnetic fields during live-line maintenance. IEEE EIC 2013., Ottawa, Kanada, 2013. 06. 02-2013. 06. 05. Paper 172. ISBN: 978-1-4673-4739-6

[Németh et al. 2012c] NÉMETH B., GÖCSEI G.: Investigation of different conductive clothing's shielding efficiency, CITTES 2013. Concordia, Argentína, 2013. 05. 07-2013. 05. 10. Paper TT 072.

[Göcsei, Németh et al. 2014a] G. GÖCSEI, **B. NÉMETH**, Á. TAMUS, I. KISS, J. MEIXNER**:** *Shielding efficiency of conductive clothing during live-line maintenance*, 11th ICOLIM, 21-23. May 2014, Budapest, Hungary, Paper: 306, DOI: 10.1109/ICOLIM.2014.6934339

[Göcsei, Németh et al. 2014b] G. GÖCSEI, **B. NÉMETH**, J. BÉRES, Z. LIPOVITS**:** *Introduction of a training center for LV and MV LLM education*, 11th ICOLIM, 21-23. May 2014, Budapest, Hungary, Paper: 351, DOI: 10.1109/ICOLIM.2014.6934372

[Kiss, Németh et al. 2014] KISS I., **NÉMETH B.,** HORVÁTH T., BERTA I.: *Improved method for the evaluation of shielding effect of objects near medium voltage transmission lines,* 32nd International Conference on Lightning Protection, 11-18. 10.2014, Shanghai, China, Paper id: 471

[Németh B. 2014a] NÉMETH B.: *Preventive Lightning protection,* International Seminar, The Korean Institute of Electrical Engineers, Society of Electrophysics and Application, 23-25. 10.2014, Gochang, South-Korea, Paper id: invited paper2

[Németh B. 2014b] NÉMETH B.: *Live working in Hungary,* International Seminar, The Korean Institute of Electrical Engineers, Society of Electrophysics and Application, 23-24. 10.2014, Gochang, South-Korea, Paper id: invited paper1