USE OF AUGMENTED REALITY IN THE SAFETY OF OPERATING ELECTRIC CAR NEAR CHARGING STATIONS

MILAN ORAVEC[1], JOZEF NOVOTNAK[2], PAVOL LIPOVSKY[2], ZUZANA KOTIANOVA[1]

[1]Department of Safety and Quality, Faculty of Mechanical Engineering, Technical University of Kosice, Kosice, Slovakia

[2]Department of Aviation Technical Studies, Faculty of Aeronautics, Technical University of Kosice, Kosice, Slovakia

DOI: 10.17973/MMSJ.2024_06_2023154

jozef.novotnak@tuke.sk

Augmented reality (AR) provides possibilities from simple displays to tools improving service in the production process. It has found justification in the field of crisis/critical situation management and also in the commercial sphere. The technologies of the digital world together with AR are directed towards the user environment and the operation of technical devices does not deal with the essence of the problem. Electric vehicle (EV) charging stations (CHS) are considered to be sources of electromagnetic fields, as are also inverters in EVs. Until now, there are standards only for stable sources, which EV is not. There are several standards for CHS, from guidelines to regulations in a specific country. The magnetic field (MF), as a component of the electromagnetic field, carries information about the state of the CHS and the environment around the EV during its charging. Information provided to the operator about the state of the environment around him when charging EV is currently at a minimal level. There is no application yet that provides a display of MF information for the operator. AR in the form of the AR Infinity platform provides such an option. The article points out the way of creating information tools using simple devices in an AR environment with a mobile phone application.

KEYWORDS

augmented reality, mobile augmented reality, Infinity platform, charging stations, electric car, magnetic field, operator safety, mobile phone

1 INTRODUCTION

The infrastructure required for the operation of EVs is closely related to the development of electromobility. The EV battery can be charged with direct or alternating current. MF as a part of the electromagnetic field is specific with regard to the possibilities of identification and with regard to the characteristics of the environment and equipment [Oravec 2019b, Oravec 2021a]. Monitoring the state of the environment using MF provides not only information for the safety of technical systems, but also for safe work. MF provides information on any change in the state of the environment or process (including EV charging) [Markova 2021].

Charging stations are a characteristic stable source for charging EVs. Classical AC charging is carried out in the frequency range up to 300 Hz [Markova 2021], since frequently the CHSs are powered from the power grid with 50 Hz/60 Hz industrial frequency and its harmonics often occur. However, inside the EV, using its built-in charger [Essaki 2020, Hirota 2011] and converter [Zhang 2019], also higher frequencies can occur, but these are often well shielded and despite the switching, the currents are used in filtered mode, e.g., in coils and windings [ICNIRP 2010].

For stable sources with the potential of MF, there are several regulations in the EU, despite the fact that there is only one directive in the EU for this area [CEN 2013]. The approach to limit values is also different in areas in a specific state. For example, in the Czech Republic and the Slovak Republic, considering the fields, there is no perspective from the field of construction and technical cleanliness of the buildings, as it is, for example, in Austria.

Regulation SBM 2015 [IBN 2015] classifies four categories of magnetic induction values for AC MF. Up to 20 nT (low), from 20 nT to 100 nT (minor), from 100 nT to 500 nT (significant) and above 500 nT (critical). SBM 2015 has limit values in magnitude lower than 3 orders of the MF limit values for stable sources according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [ICNIRP 1998. ICNIRP 2014]. In its recommendations, there is a flat area of AC magnetic field values in the frequency band of industrial frequencies (25 Hz – 300 Hz), whereas other limits are stated with dependence on the frequency. ICNIRP classifies two categories of exposures - occupational and general public (Fig. 1).

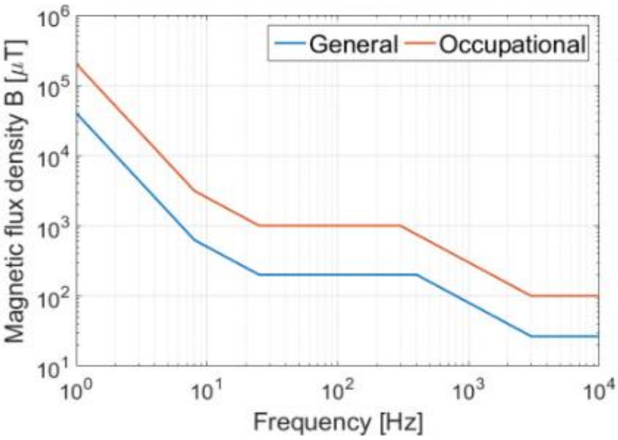


Figure 1. Limit values according to ICNIRP

Development of opinions on the limit values of MF according to ICNIRP still remains in the form of AC values, but since MF is a vector field, also its direction and gradient should be considered. The effective value of MF BRMS as a relevant data for the description of MF is insufficient. There is still no standard or guideline for fields during EV charging, e.g., for the AC/DC converter system built-in the EV, since car is not considered as a stable source.

Although there are no standards or guidelines, the augmented reality (AR) could be a good tool to serve in enhancing the safety in terms of exposure. AR is a digital tool that uses a combination of visual reality and digital information in the form of resulting information, which creates a resulting perception for a person. The information can be in a text form or in a graphic form regarding the specified problem. The data, in the form of embedded information between the real-world object and the eye, can be embedded by everyday devices such as mobile phones, tablets, or glasses.

The founder of the AR idea in the fifties of the last century was videographer Morton Heilig, who built the first AR concept called Sensorama [Barmpas 2020]. Sensorama was based on mechanical instruments. Ivan Sutherland, in 1968, built the first system of virtual and augmented reality (mixed reality). Because computers in those days did not have sufficient computing power, the system could only be visualized in real time using simple wireframe model [Arth 2015, Carmigniani 2011, Sutherland 1969a]. In 1975, Myron Krueger presented a computer system that could coordinate the movement of a graphic object with the user's reactions. Cameras captured silhouettes of users and projected them onto a screen where they could interact with virtual objects [Mandal 2013]. Bell Helicopter company has been exploring analogue systems for helicopter pilots to land in the dark using infrared cameras. In the late 1990s, students at Columbia University developed Mobile Augmented Reality System 3 (MARS3) [Feiner 1997], which brought AR out of the lab into the outdoor applications, and after this more advanced applications emerged and research expanded to various fields of study.

The current form of AR resources is significantly richer. The computing power of mobile portable devices has brought the possibilities of applying AR based on different platforms in the form of mobile AR (MAR). Applying AR is suitable from commercial applications to the field of crisis management [Oravec 2021b] and operational process management.

2 METHODOLOGY AND MATERIAL

2.1 Experimental Method and Modeling in the AR Infinity Environment

Local MF at CHS is formed by the passage of electric current through CHS elements/devices. For this MF, it is possible to measure the magnetic induction components *Bx, By, Bz*, in the *x, y, z* directions of the rectangular orthogonal system and determine the resulting MF vector from them. The entire procedure for identifying MF in the vicinity of CHS is described in detail in [Oravec 2022]. After the measurement of the MF values at a specific point in space near the CHS, it is necessary to process the measured MF values for the purpose of comparison with the MF limit values. The sequence of steps is shown in Fig. 2.

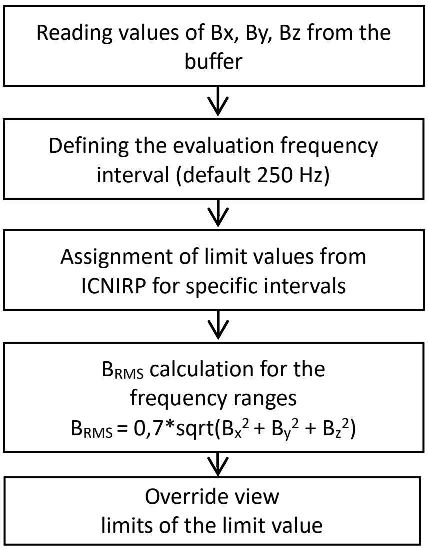


Figure 2. Sequence of steps for determining the limit value for modeling input to the AR environment

The AR Infinity platform is distributed under Microsoft, which ensures compatibility with Microsoft products and connectivity to mobile devices working on iOS and Android platforms. Separate rules apply to the AR environment of the Infinity platform from Microsoft, which must be considered when performing the modeling. The sequence of steps for modeling the AR environment is on Fig. 3.

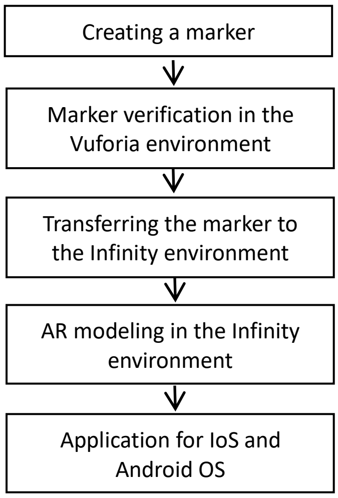


Figure 3. The sequence of creating an application in the Infinity environment

2.2 Measurement and Evaluation of Measured Data of MF at Charging Station

Identification of MF in the vicinity of the CHS was carried out with a VEMA-040 magnetometer (Fig. 4), however also modern MEMS (micro electro-mechanic system) sensors could be used, like in the utility model registered at the Industrial Property Office of the Slovak Republic under number UV 9705 from 2022 [Lipovsky 2022b]. The magnetometer can be placed with/within CHS or EV. It provides sufficient information on all MF parameters.

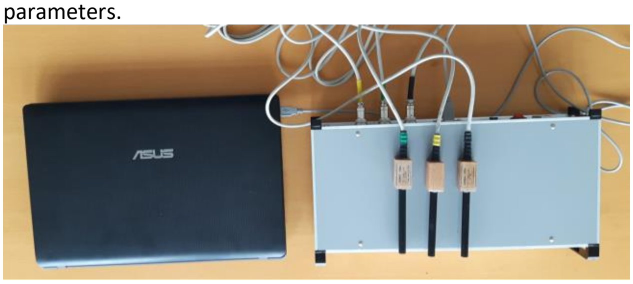


Figure 4. Magnetometer VEMA-040 with probes

VEMA-040 is a fluxgate magnetometer. It allows simultaneous measurement of 3 components of the magnetic induction vector in selected directions. The device works with a constant sampling frequency of 1 kHz and has the frequency band from DC to 250 Hz [Oravec 2020]. Probes for measuring magnetic induction *Bx, By, Bz* are generally placed in the measuring non-magnetic fixture in the shape of an orthogonal right-hand arrangement. This arrangement allows further calculations, either scalar or vector. Newer, more compact solutions like MEMS [Lipovsky 2022b] are small and just as powerful. MEMS in MF measurement enabled miniaturization to such an extent that they can be mobile or an element of any technical device (Fig. 5). The three-axis MF sensor is smaller compared to the size of a coin. The analytical and Wi-Fi unit can be also on small PCB (printed circuit board) and they can be part of a small embedded system.

The limitations in dimensions are mainly in the size of chips and the bandwidth is often limited by the sensor itself or in microcontrollers by the filtering algorithms and bus speeds. The MEMS described in [Lipovsky 2022b] is a good basis for technical measurements of MF as well as a CHS element. The analysis is carried out in a small microcontroller with ARM

Cortex M4 or M7 that is connected to the MEMS sensor, output is in the form of text or graphic data.

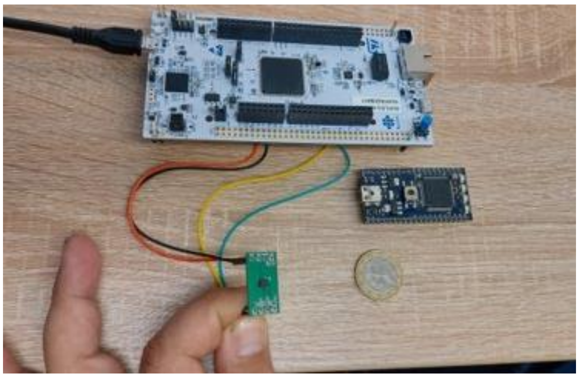


Figure 5. Embeddable MEMS sensor example connected to a microcontroller

2.3 Course of the Experiment

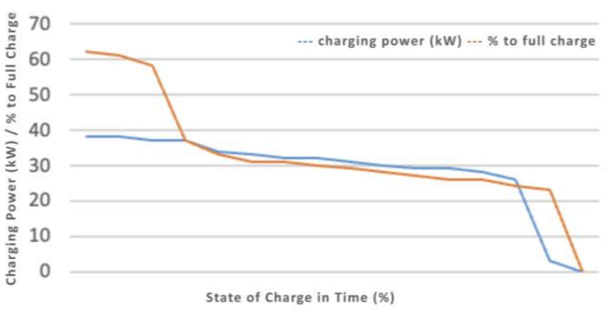


Figure 6. Nissan Leaf EV charging management (blue – charging power in kW, red – how many % remain to charged state)

The MF represented by the magnetic induction parameter *B* near the CHS of EV is dependent on the magnitude of the current and therefore on the charging power. EV charging was analysed from multiple CHS. Fig. 6 shows the charging management of the 2nd generation Nissan Leaf EV. The battery had the capacity of 50 kWh. The charging current can reach 130 A in the 1st stage of charging process. These are characteristic parameters for the middle class EV [Trentadue 2020].

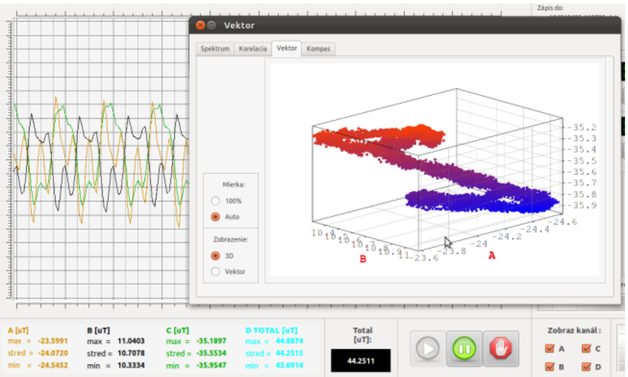


Figure 7. Position of the endpoints of the MP rotating vector at 44 kW EV charging

Fig. 7 shows the trace of MF vector tip during Nissan Leaf EV charging [Oravec 2022]. Vector is shown in the VEMA magnetometer software; however, this visualization can be carried out also in different softwares and program scripts (e.g. in Python programming language). In the left part of the figure is the time development of *Bx, By, Bz*.

In the left part of Fig. 8 the time development of *Bx, By, Bz* is displayed, and the window shows the corresponding amplitude spectrum of *Bx*. Similar visualizations are possible for *By* and *Bz*.

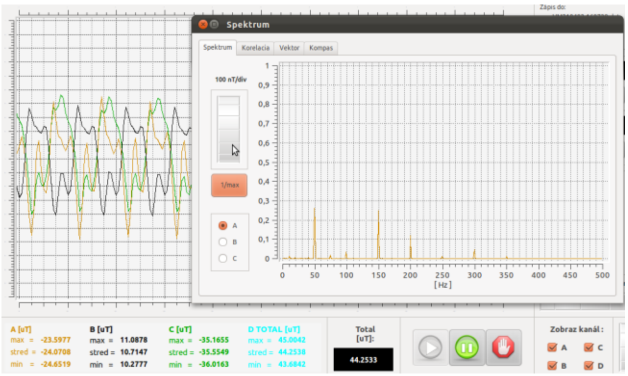


Figure 8. Display of the *Bx* amplitude spectrum when charging 44 kW

In a similar way, it is possible to evaluate the subsequent MF parameters for the purpose of modeling phenomena in AR Infinity at any charging performance.

2.4 Creation of an Application in the AR Environment of the Infinity Platform

Applications for AR were developed in two variant groups, which use a different approach to the acquired and displayed data in the AR environment. Each charging unit has its own QR code for the corresponding plug, which in the AR environment is read as an image (Fig. 9) and not as a QR code.

Figure 9. Selected marker for pairing CHS and AR environment

The first variant is a static variant, which consists in displaying the already measured and evaluated MF values in the vicinity of the CHS during EV charging. The chosen form can be in the AR Infinity environment:

A1 – Sound warning after loading the marker in the AR Infinity environment and reaching the distance from the CHS where the limit value is. The audio message will also be displayed as text information on the mobile device.

A2 – Visual warning in the AR environment, where the borders of the MF will be displayed in the form of a line around the CHS when charging the EV. Similarly, it is possible to create subsequent information that compares the measured and limit value of MF. All solutions of this group are based on identifying the MF near the CHS when charging the EV, with the subsequent creation of alerts in the AR environment.

The second variant is the provision of information about the state of the MF in a specific space (dynamic variant):

In this case, the values of magnetic induction *Bx, By, Bz* are measured in real time and evaluated according to Fig. 2. Subsequently, they are displayed in the AR environment according to the created procedure (Fig. 3). Such realizations assume solutions based on MEMS systems built into CHS, or in EV, since their size compared to classic, but more precise magnetometers, is smaller.

The form of displaying dynamic data of MF values with respect to the limit value of MF according to Fig. 1 can be:

B1 – Sound announcement of the distance from the source, where the limit value of MF is when charging EVs according to Fig. 2. This distance changes depending on the management of charging in the sense of Fig. 6.

B2 – Drawing and highlighting with a line defining the distance with MF limit values. This distance will change depending on the charging management in the sense of Fig. 6.

B3 – In the form of a display of the time development (Fig. 10) of magnetic induction *Bx, By, Bz*, or another representative parameter of MF.

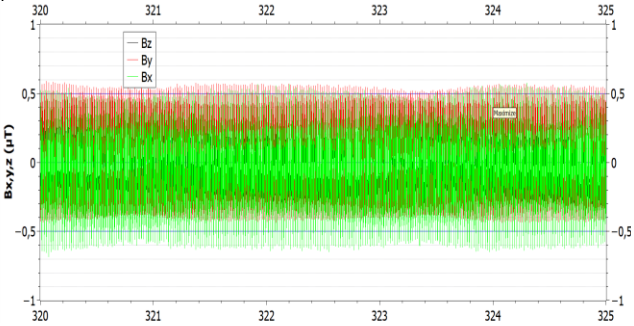


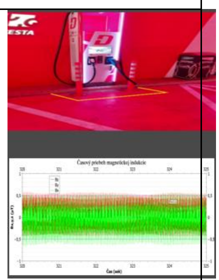
Figure 10. Course of magnetic induction *Bx,By,Bz* in real time (seconds)

Even in this case, there are many other solutions by which it is possible to provide information easily, commercially and interestingly about the MF in the place where the CHS operator is at a specific time when charging EVs. In terms of the above-mentioned solutions A1, A2 or B1-B3 were realized models for AR Infinity. Tab. 1 shows the sequence of steps for creating a model in the AR Infinity environment and verifying it for use on a mobile phone. Tab. 2 shows modeled and tested static and dynamic solutions for displaying MF in the CHS space during EV charging.

Table 1. Creating an AR Infinity environment for a mobile phone and testing EV charging locations and environments with a mark

	
Testing the QR code as an image (marker) in the ARInfinity environment (it is also possible with code number only)	Mobile verification in a space outside charging station displayed on a mobile phone
	

Table 2. Outputs in the AR Infinity environment on a mobile phone

Group A solutions (static solutions)		
	**A1 – sound and text message** After the marker is loaded (two markers were tested), a message about the limit distance from the NS, which should be observed when charging the electric car, will be played in the form of a recording (e.g. mp3 format): *The limit value of MP according to the limit values in Slovak republic is at a distance of 30 cm from NS. We recommend that you do not stay in this area permanently.* At the same time a text message will be displayed - above the finger on the mobile phone. AR Infinity has the option of directly connecting a recording in mp3 format or text in pdf format.	
	A2 – image, video on mobile phone The border with the limit value of MP when charging EV will be displayed after reading the marker on the mobile phone in the form of an image with the limit value of MP near the CHS (yellow border). The display is a screenshot of a mobile phone screen in the AR Infinity environment. AR Infinity has the option of directly attaching an image, in *.jpeg format, or a video that appears or plays after the marker is loaded.	
Group B solutions (dynamic solutions)		
	**B2 – drawing and highlighting with a line the sliding limit value of MF** After reading the marker, the limit distance of the magnetic field will change depending on the charging management system and the position of the MEMS device. MF is a function of charging current and also MEMS position has to be considered. Infinity AR has the option of directly attaching an image in *.jpeg format, or by activating the button that appears after loading the marker. Subsequently, after activating the button, the limit value of MP will be displayed depending on the position of the MEMS sensor and current state of the charging process. **B3 – in the form of displaying the time course of magnetic induction B_x, B_y, B_z** After loading the marker, a figure (solution B2) is displayed at the position of the operator, into which the measured time development of the MF values is inserted. It can also be supplemented with a text message (solution B1).	

3 DISCUSSION

4.1 AR, MA, MARS Tools and Their Capabilities and Usability

AR is directed towards MARS and devices that are used every day [Arth 2009]. Static solutions A1-A3 can be modeled directly in the AR Infinity environment. The marker in this environment is crucial and must be created in the Vuforia environment for AR Infinity. The readability of the marker is affected by many parameters, such as lighting, reading angle, distance and size of the marker, etc. This can be viewed as a weakness of the AR Infinity environment. The second problem is communication with the server, where a custom product was created in the AR Infinity environment. To transfer extensive data, it is necessary to have a powerful transmission network and the display device itself (in this case, a mobile phone). For simple static solutions such as A1 - A3, this environment is sufficient.

In the case of solving dynamic tasks, where the MF measured near the CHS is displayed in real time, it is not possible to use this solution directly. For dynamic solutions B1 - B3, the principle of optical information layering was used – after loading the marker, AR Infinity is used as an underlying static display, into which a window with dynamically evaluated parameters is inserted. With the software (SW) solution, it is possible to insert any dynamically changing information. Such a solution is more suitable to be modeled outside the AR Infinity environment as a stand-alone one, communicating with the cloud application/server.

Device with AR, or shared performance from the server must provide sufficient information and be efficient. Accuracy, resolution, image compression and other image parameters place demands on SW and hardware (HW) with MAR. There are several limitations that AR has not yet overcome. The minimum requirement for creating a marker is the resolution of 600 dpi for photographed or created objects. Up to 1200 dpi is recommended. In the case of creating 3D objects as markers, it is necessary to take into account large data files, which have to be transferred, edited and dynamically worked with in applications with AR and MAR. The Infinity environment itself is easy to handle, but it does not provide some functionalities that can be created in other environments and create similar functionalities as AR. It was pointed out in the utility model 8111/SR [Oravec 2018]. Sharing as a principle of information layering can also be achieved in a different way than the procedures in AR are created. AR Infinity has prescribed formats of graphic, image inputs, which are dynamically worked with and are demanding on SW and HW resources.

Creating a user-friendly environment for creating projects in AR is still only in the hands of IT specialists. The amount of work required to create the final product is therefore limited financially and limits the application space for AR [Siriwardhana 2021]. AR has great potential for creativity, which is necessary for creating user-interesting outputs. A problem with some MARS devices, e.g., glasses are physical and psychological barriers. In March 2023 [Korn 2023, Lukpat 2023], Google ended the development of AR using glasses. Accommodation, the display of an image by both human eyes, has not yet been mastered in these devices. These are the limits that other devices have no problem with. Audio information can be heard even if a mobile phone, as a MARS device, is placed in a pocket. AR in its current form demands the transfer of a large amount of data, which is necessary to create a dynamic image in real time and space.

MEMS bring new trends to AR modeling, where it is possible to use the actual measured values of the technical parameters of the environment. Trend is to orientate not only on informing about the state of the space, but also to process management in real time.

4.2 Information and Its Formation in the AR and MARS Environment

Text information should have 5 “W” (what, where, when, who and why). Image information provides a wider spectrum of information. From this point of view, it is more suitable for the AR environment, but more demanding on the amount of data for work in the AR environment. Video provides description as time-space information and not just a sequence of images. Sound and image are even more demanding than working with images. The choice of these parameters in the AR and MARS environment makes it possible to provide enough essential information. ChatGPT from v.4 provides simple tools for image processing into an AR environment. This is primarily about the creation of markers. If in Vuforia the emphasis was put on image processing with classic tools, in the ChatGPT environment the UI tools are saving time and one can achieve a comparable result.

AR using the analysis tool of CADx systems has been applied in the construction industry or in the engineering industry. In these systems, AR is used only as a tool for sharing information through simple portable devices such as a tablet or mobile phone. A procedure, where the analysis was performed in an analytical element outside the AR environment with inputs from process sensors is not used. However, CADx systems are not classic software tools for process management.

4 CONCLUSIONS

AR tools are used today for education, games, advertising, but it is possible to create software products in the AR and MARS environment to increase safety and inform about the state of the environment. Until now, tools based on simple pre-analysed and created models have been predominantly used. In these cases, the information has been presented as text, image or video for viewing in an AR environment. Dynamic solutions of time-space tasks with inputs from environmental sensors or specific MEMS as was referred to in the paper were not used. These solutions provide a dynamic view of solving security problems not only in the area of CHS. The fear of MF is caused by unfamiliarity of the problem, different view of limit values of MF in EU member states, despite the existing single directive. Electromobility, with its shortcomings, will bring more questions than answers for a long time, which have to be solved.

ACKNOWLEDGMENTS

The contribution was supported by the project APVV-19-0367 "Integrated process safety management approach framework for the smart enterprise".

REFERENCES

[Arth 2009] Arth, C., et al. The History of Mobile Augmented Reality Developments in Mobile AR over the last almost 50 years. Austria, Graz: Univ. of Technologies, Inst. for Computer Graphics and Vision, 2015.

[Arth 2015] Arth, C., et al. The History of Mobile Augmented Reality, 2015.

[Barmpas 2020] Barmpas, Z.N. Development of an iOS, Augmented Reality for disaster management. Lund: Lund University, Dept of Physical Geography and

Ecosystem Science, 2020. Available from: https://lup.lub.lu.se/student-papers/search/publication/9007282

[Carmigniani 2011] Carmigniani, J., Furht, B. Augmented Reality: An Overview. Handbook of Augmented Reality. Springer: New York, 2011. ISBN 978-1-4614-0063-9.

[CEN 2013] European Committee for Standardization (CEN). Directive 2013/35/EU on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (EM Fields). CEN: Brussels, Belgium, 2013.

[Essaki 2020] Essaki, R., et al. AC-DC Converter for Electric Vehicle Charger. Int. Research J. of Engineering and Technology (IRJET), 2020, Vol. 7, No. 6.

[Feiner 1997] Feiner, S., et al. A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment. Personal Technologies, 1997, Vol. 1, pp. 209-217.

[Hirota 2011] Hirota, M., et al. Development of New AC/DC Converter for PHEVs and EVs. SEI Technical Review, 2011, Vol. 73, pp. 68-72.

[IBN 2015] IBN. Standard of Building Biology Testing Methods, SBM-2015. Available from: buildingbiology.com/site/downloads/standard-2015-englisch.pdf

[ICNIRP 1998] ICNIRP. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). Health Phys., 1998, Vol. 74, No. 4, pp. 494-522.

[ICNIRP 2010] ICNIRP. Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz - 100 kHz). Health Phys., 2010, Vol. 99, No. 6, pp. 818-836.

[ICNIRP 2014] ICNIRP. Guidelines for Limiting Exposure to Electric Fields Induced by Movement of the Human Body in a static magnetic fields and by time-varying magnetic fields below 1 Hz. Health Phys., 2014, Vol. 106, No. 3, pp. 418-425.

[Korn 2023] Korn, J. Google Will Stop Selling Glass as It Looks to Cut Costs. CNN, March 16, 2023. Available from: https://www.cnn.com/2023/03/16/tech/google-glass-gone/index.html

[Lipovsky 2022] Lipovsky, P., et al. Device for evaluating the parameters of the low-frequency magnetic field of electric mobile sources and the measurement procedure. Utility Model 9705, Slovakia, Industrial Property Office of the SR, 2022. (in Slovak)

[Lukpat 2023] Lukpat, A. Google Glass is Going Away, Again. The Wall Street J., March 16, 2023. Available from: https://www.wsj.com/articles/google-glass-is-going-away-again-e7a6d8c8

[Mandal 2013] Mandal, S. Brief Introduction of Virtual Reality & its Challenges. Int. J. of Scientific & Engineering Research, 2013, Vol. 4, No. 4, pp. 304-309.

[Markova 2021] Markova, I., et aL. Magnetic Fields of Devices during Electric Vehicle Charging: A Slovak Case Study. Symmetry, 2021, Vol. 13, No. 11, 1979. DOI: https://doi.org/10.3390/sym13111979

[Oravec 2018] Oravec, M., et al. A device for the mutual use of image data between cars in mutual circulation. Utility Model 8111, Slovakia, Industrial Property Office of the SR, 2018. (in Slovak)

[Oravec 2019] Oravec, M., et al. Device for Slip Control by Identifying the Magnetic Field of Elements of an Asynchronous Motor with a Frequency Converter. Utility Model 8860, Slovakia, Industrial Property Office of the SR, 2019. (in Slovak)

[Oravec 2020] Oravec, M., et al. Low Frequency Magnetic Field – Instruments, Measurements, New Technologies. Ostrava: SPBI, 2020. ISBN 978-80-7385-230-6. (in Slovak)

[Oravec 2021a] Oravec, M., et al. Low-Frequency Magnetic Fields in Diagnostics of Low-Speed Electrical and Mechanical Systems. Sustainability, 2021, Vol. 13, No. 16, 9197. DOI: doi.org/10.3390/su13169197.

[Oravec 2021b] Oravec, M., Adamaec, V., Tomanova, K. Augmented reality, ARSandbox modeling and its use in crisis management (in Slovak). Spektrum, 2021, Vol. 21, No. 2, pp. 16-23. ISSN 1804-1639.

[Oravec 2022] Oravec, M., Lipovsky, P. Low Frequency Magnetic Fields near Charging stations for Electric Vehicles. MM Science Journal, 2022, pp. 5962-5968. DOI: 10.17973/MMSJ.2022_10_2022088.

[Siriwardhana 2021] Siriwardhana, Y., et al. A Survey on Mobile Augmented Reality With 5G Mobile Edge Computing: Architectures, Applications, and Technical Aspects. IEEE Communications Surveys & Tutorials, 2021, Vol. 23, No. 2, pp. 1160-1192.

[Sutherland 1969] Sutherland, I. A head-mounted three dimensional display, In: Proc. of the AFIPS Fall Joint Computing Conf., December 9-11, 1969, pp. 757-764.

[Trentadue 2020] Trentadue, G., et al. Low Frequency Magnetic Fields Emitted by High-Power Charging Systems. Energies, 2020, Vol. 13, No. 7, 1594.

[Zhang 2019] Zhang, G., Zheng, Z. Onboard Charging DC/DC Converter of Electric Vehicle Based on Synchronous Rectification and Characteristic Analysis. J. of Advanced Transportation, 2022.

CONTACTS:

Prof. Ing. Milan Oravec, PhD.
Ing. Zuzana Kotianova, PhD., MBA
Technical University of Kosice, Faculty of Mechanical Engineering, Department of Safety and Quality
Letna 1/9, 042 00 Kosice-Sever, Slovak Republic
milan.oravec@tuke.sk, zuzana.kotianova@tuke.sk

Ing. Jozef Novotnak, PhD.
Assoc. Prof. Ing. Pavol Lipovsky, PhD.
Technical University of Kosice, Faculty of Aeronautics, Department of Aviation Technical Studies
Rampova 7, 040 01 Kosice, Slovak Republic
Jozef.novotnak@tuke.sk, pavol.lipovsky@tuke.sk