



Design of Nano-scale Electrodes and Development of Avatar-Based Control System for Energy-Efficient Power Engineering: Application of an Internet of Things and People (IOTAP) Research Center


Vardan Mkrttchian, HHH University, Brisbane, Queensland, Australia

 <https://orcid.org/0000-0003-4871-5956>

Leyla Gamidullaeva, Penza State University, Penza, Russia

 <https://orcid.org/0000-0003-3042-7550>

Rinat Galiautdinov, Independent Researcher, Rome, Italy

 <https://orcid.org/0000-0001-9557-5250>

ABSTRACT

In this article is described the avatar-based energy-efficient power engineering control system, which is based on authors results published previously related to development of an Internet of Things and people (IOTAP) and the digital twins systems. The authors are described the development of the innovation tools for digital twins system, based on Avatar-based Control Techniques.

KEYWORDS

Avatar-Based Control System, Energy-Efficiency, Internet of People (IoP), Internet of Things (IoT), Nanometric Structured Electrodes, Self-Healing Capacitor

INTRODUCTION

Electric capacitors are the essential part of energy generation, transmission and accumulation systems. They are widely used in reactive power compensation systems in order to increase the capacity of transmission lines, in capacitive voltage dividers, and power electronics. Energy effective high-voltage electrical capacitor is a key factor of the modern electrical power equipment design. Nowadays the most frequently used capacitors in the above-mentioned areas are the devices designed in the 1980s by the soviet capacitor industry. These capacitors' parameters are far from modern energy-efficiency and ecological standards. Being based on aluminum foil electrodes and liquid dielectrics impregnation, these capacitors have the characteristics, which are listed below. The significant improvement

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of capacitors' specific volume characteristics is possible when metallized electrodes replace the conventional foil electrodes. The metallized electrodes capacitors or metal-film capacitors (MFC) have the feature of so-called self-healing (SH).

This article is dedicated to the investigations of physical processes of electrodynamic destruction of thin metal layers during SH. In spite of the fact that the SH process has been studied over several decades, the clarity of the SH physics remains unclear. There is no agreement among the proposed models regarding the role of the electric explosion and the micro discharge phenomena. The design of the capacitors is based on empirical approaches.

The relevance of this work is confirmed by the fact, that similar investigations have been conducted by China, France, Finland, and USA scientists for the last years. It is obvious that clarifying of the metallized electrodes degradation mechanisms is a key to efficient capacitors development. The aim is characterized by the scientific novelty and no investigations of segmented MFC's dielectric systems have not been conducted so far. Meanwhile, in the other countries, this aim has a high priority. There is some information on ABB's pilot version of a high-voltage capacitor with segmented metallization, which has best energy-efficiency parameters in class.

BACKGROUND

Metal film capacitors are widely used in modern technology: from household electrical appliances to high-voltage pulse systems. The wide distribution of capacitors of this type is due to the high specific energy and high reliability. The high reliability of these capacitors gives them ability to heal themselves – this is a restoration of their performance after a dielectric breakdown. At this time, work is at the stage of increasing the specific energy and it is possible due to the use of new dielectric materials with a large relative dielectric constant and by improving of electrode systems to increase operating electric field's strength. Currently the research is on a stage of creation of a new hybrid polymer films (consisting of two or more). These films are obtained by hot pressing technology, followed by a broach. The advantage of this technology is that during production, ready-made original polymer films with high electrical strength and rather low dielectric losses are used. Such polymer films today can increase the specific energy of the IPC in 2 - 2.5 times.

Another promising direction in the creation of new materials is production of composite materials based on polymer matrix and inorganic filler. As a matrix, it is possible to use traditional polymers for capacitor films: polypropylene and others. There are various types of inorganic dielectrics in the role of filler, it also includes ferroelectric ceramics. Scientists working in this direction predict growth in the specific energy of capacitors based on such materials by 10 or more times. However, a high dielectric constant value does not guarantee a great potential for the use of these composite materials. There is no data in the literature on the electrical strength and dielectric spectroscopy for recently created composite materials. Such materials may be completely inapplicable in capacitor technology.

The improvement of electrode systems mainly goes along the path of creation of optimal electrodes for limiting the self-healing energy. Segmented or ultrathin electrodes are used for this purpose. The low value of the SH energy gives less damage to the dielectric and electrodes and a lower probability of thermal breakdown of the capacitor and as a result higher reliability. However today there are not so many researches in open press on segmented electrodes or electrodes with ultrafine metallization. Quite often the authors of the articles mention that these technologies make it possible to reduce the energy of the solar wind and to increase the specific energy of the IPC in comparison with traditional electrodes, however, the details of the production technology and design features of the capacitors are not disclosed. This is probably because of the privacy policy of the capacitor manufacturers. In addition, there is no clear opinion on the ways to limit SH in the frame of preference.

The given ability to SH IPC can be used in forced modes of operation. Forced modes imply an increase of energy efficiency due to exceeding of the limit loads which leads to reduction of the capacitors' service life. The greatest practical interest represents the work of the IPC in

modes with an increased electric field strength and high current load, which is associated with their use in high-energy pulsed devices. In this application, the mode of operation is characterized by a high amplitude of the current pulse (up to several tens of kilo amperes) and short duration (units of milliseconds or less), while the service life of capacitors does not exceed several tens of thousands of pulses. However, the work of the IPC in such the modes remains hardly studied. One of the main reasons of failure of metal-film capacitors in forced modes is the degradation of electrode systems. The electrode system includes capacitor electrodes, a contact node, a lockout and an external output. During the operation, the electrodes and the contact assembly are especially susceptible to destruction; however, the mechanisms of their degradation are different and depend on the mode of operation. The degradation of the electrodes is primarily due to self-healing processes when IPC operates in the high voltage mode. For the case when SH is a lost part of the electrodes' area it leads to decreasing in capacity. Carbon gets formed which is deposited in the breakdown zone as a result of decomposition of the dielectric. This leads to deterioration of the insulating properties of dielectric. There are several theoretical models of self-healing aimed at determining the energy of the solar energy, the area of the DM zone, and the duration of the solar energy process. Each theoretical model takes a number of assumptions. However, in some cases, the accepted assumptions significantly influence the results and lead to serious discrepancies with experimental data. A significant disadvantage of all SHa theory is that it was tested on model capacitor samples and was not always compared with real IPCs. The problem with this approach is that in real capacitors, the capacity of which can be several hundred microfarads, and the breakdown voltage is several kilovolts, the SH energy will be several orders of magnitude higher than in model samples.

MAIN FOCUS OF THE ARTICLE

Issues, Controversies, Problems

This leads to a serious discrepancy with theoretical ideas. Therefore, today there is no optimal theory of SH. During the operation of the IPC in a pulsed mode, their failure is primarily associated with the loss of capacity because of SH, while a way less work is devoted to the degradation of contact nodes. When operating in pulsed mode, the amplitude value of the current can reach several kiloamperes. In this case, the failure of the IPC will be caused by the destruction of the contact of the electrode and sopping. In addition to the listed mechanisms for the degradation of IPC, an electro migration mechanism of destruction of electrode systems is possible. Electro migration is a well-known process in integrated circuits and it is one of the causes of device failure. However, this process was never considered as the mechanism of destruction of the IPC electrodes. Nevertheless, the influence of this mechanism of degradation on destruction of the process of metallized capacitor electrodes is not excluded. In addition, it is shown that electro migration destruction can manifest itself in microsecond time scales, while in the elements of microelectronics, electro migration occurs in the course of days, months, and even years.

Digital twins are widely used in modern industry. The digital twin is a dynamic virtual model of a system, process or service. The digital twin continuously learns and updates its parameters, receiving information from a variety of sensors, correctly representing the state of a physical object. They use current data from sensors, from control devices, from the external environment when learning; it combines actual data with the knowledge gained from specialists in this field. Digital twins allow you to monitor systems and processes in real time and analyze data in a timely manner to prevent problems before they occur, schedule preventive maintenance, reduce downtime, open up the new business opportunities and plan the future updates and new developments. Digital twins of objects with distributed parameters are mathematically boundary value problems for partial differential equations.

Solutions and Recommendations

The study of the laws of electrodynamics' destruction of nanometer metal layers and structure is based on them in conditions of high densities of the input energy. Establishing patterns of influence of polymer and liquid dielectrics in the process of electrodynamics is destruction of metallized electrodes. Development of model of electrodynamics' destruction of structured electrodes of various geometries uses CAD / CAE systems. Development use of the "Digital Twin" is high-voltage metal-film capacitor. Digitalization implies great opportunities for all aspects of society. We are currently at what can be seen as the fourth wave of digitalization. The first wave concerned the introduction of computers in many parts of society. The second wave, in the form of the Internet, made it easy to access and share information. The third wave is the mobile Internet that enables accessing and sharing information regardless of where you are. With the fourth wave of digitalization, it is not just people who use the Internet to access and share information, but also different types of objects, such as vehicles, appliances, and machinery. All parts of our society will be affected by this phenomenon, commonly referred to as the Internet of Things (IoT).

A critical component for making IoT successful is that it creates value for the users. To make IoT usable and useful is the main focus of the research conducted within the Internet of Things and People (IOTAP) research centre. In addition to concrete goals regarding publications, technology transfer contributions, etc., IOTAP has the following three main impact goals:

- IOTAP should be a reason for a company to place their operations in the Penza region;
- IOTAP should contribute to that public organizations in the region are leading in the application of IoT;
- IOTAP should foster excellent IoT researchers.

The Avatar-Based Control Techniques of Vardan Mkrttchian was published in journals and books of IGI Global in 2014-2018 (Mkrttchian et al., 2014; Mkrttchian, 2015; Mkrttchian, et al., 2016; Mkrttchian & Aleshina, 2017; Mkrttchian & Belyanina, 2018). For the purpose of breaking down cultural and language barriers, which is the primary objective of this book, in the article the authors propose to use the technology and methods of the avatar-based management technique for training and improvement of technology of response to intervention (RTI), successfully used in the US in the special system. Response to intervention has been in existence for only a short period of time; also, it has had a powerful impact on the academic achievement of peoples across the United States. The National Center on Response to Intervention (2010) defined Response to Intervention as a delivery service model that integrates assessment and intervention within a multi-level prevention system to maximize people's achievements and reduce behavior problems. With Response to Intervention, schools identify students at risk for poor learning outcomes, monitor student progress, provide evidence-based interventions and adjust the intensity and nature of those interventions depending on a student's responsiveness, and identify students with learning disabilities or other disabilities. To solve the problems with the Russian language, they propose using the previously obtained teaching technologies together with the RTI technology for a new field of application - training the Russian language for personnel of state corporations (Vertakova & Plotnikov, 2014; Mkrttchian, 2017).

The article's authors developed innovation tools based on the results of the analysis of citizens' deliberation in social networks on topics related to online services, using Intelligent Visualization Techniques for Big Data Analytics with Avatar-Based Management Techniques introduced by professor V. Mkrttchian in 2018, in his book "Avatar-Based Learning and Teaching in Modern Educational Environments: Emerging Research and Opportunities" (Mkrttchian, et al., 2019). Social networks and the blogosphere, which is a popular and active area of mass communication, may become the subject of study and data source for the demand for e-government services. Social networks have great popularity among Russian citizens. According to com.Score, nearly every Russian Internet

user (99.7% of the average domestic Internet users) has an account in social networks. Scale users of Russian social networks account for more than 52 million people. The average Russian social network user spends 12,8 hours per month on social networks, which is the highest rate in the world (the world average is 5.9 hours per month) (<https://ria.ru/society/20171027/1507700280.html>). Over the past five years, the social network came on the audience of the Central Russian TV channels. These facts highlight the demand and popularity of social media in Russia, as well as the possibility of using the discussions in social networks to identify attitudes, opinions of citizens and their assessment of the activities of the state.

The Intelligent Visualization Technique is a process of presenting data in the form of an image in order to maximize the convenience of understanding them; giving a visible form to any conceivable object, subject, process, and so on.

CONCLUSION

This article is dedicated to the investigations of physical processes of electrodynamics destruction of thin metal layers during self-healing Nano metric structured electrodes.

This article is described Avatar-Based energy-efficient power engineering Control System, based authors results published in IGI Global as an Internet of Things and People (IOTAP) and digital twins are used.

This article developed for digital twins the innovation tools, based Avatar-Based Control Techniques.

REFERENCES

- Grieves, M. (2014). Digital Twin: manufacturing excellence through virtual factory replication [white paper]. Academic Press.
- Madni, A. M., & Madni Lucero, S. D. (2019). Leveraging digital twin technology in model-based systems engineering. *Systems*, 7(1). doi:10.3390/systems7010007
- Mkrttchian, V. (2015). Use Online Multi-Cloud Platform Lab with Intellectual Agents: Avatars for Study of Knowledge Visualization & Probability Theory in Bioinformatics. *International Journal of Knowledge Discovery in Bioinformatics*, 5(1), 11-23. Hershey, PA: IGI Global. doi:10.4018/IJKDB.2015010102
- Mkrttchian, V. (2017). Project-Based Learning for Students with Intellectual Disabilities. In P. L. Epler (Ed.), *Instructional Strategies in General Education and Putting the Individuals With Disabilities Act (IDEA) Into Practice* (pp. 196–221). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-3111-1.ch007
- Mkrttchian, V., & Aleshina, E. (2017). *Sliding Mode in Intellectual Control and Communication: Emerging Research and Opportunities*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-2292-8
- Mkrttchian, V., & Belyanina, L. (Eds.). (2018). *Handbook of Research on Students' Research Competence in Modern Educational Contexts*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-3485-3
- Mkrttchian, V., Bershadsky, A., Bozhday, A., Kataev, M., & Kataev, S. (Eds.). (2016). *Handbook of Research on Estimation and Control Techniques in E-Learning systems*. Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9489-7
- Mkrttchian, V., Kataev, M., Shih, T., Kumar, M., & Fedotova, A. (2014). Avatars “HHH” Technology Education Cloud Platform on Sliding Mode Based Plug-Ontology as a Gateway to Improvement of Feedback Control Online Society. *International Journal of Information Communication Technologies and Human Development*, 6(3), 13-31. doi:10.4018/ijicthd.2014070102
- Mtega, W. P., Dulle, F., & Ronald, B. (2013). Understanding the knowledge sharing process among rural communities in Tanzania: a review of selected studies. *Knowledge Management & E-Learning: An International Journal*, 5(2), 205-217. Retrieved from <http://www.hku.hk/>
- Obrenovic, B., & Qin, Y. (2014). Understanding the concept of individual level knowledge sharing: a review of critical success factors. In *Information and Knowledge Management* 4(4), 110–119. Retrieved from www.iiste.org
- Uhlemann, T. H. J., Schock, C., Lehmann, C., Freiburger, S., & Steinhilper, R. (2017). The digital twin: demonstrating the potential of real time data acquisition in production systems. *Procedia Manufacturing*, 9, 113-120.

ADDITIONAL READING

Mkrttchian, V. (2011). Use ‘hhh’ technology in transformative models of online education. In G. Kurubacak & T. VokanYuzer (Eds.), *Handbook of research on transformative online education and liberation: Models for social equality* (pp. 340-351). Hershey, PA: IGI Global.

Mkrttchian, V. (2012). Avatar manager and student reflective conversations as the base for describing meta-communication model In U. Demiray, G. Kurubacak & T. VokanYuzer (Eds.), *Meta-communication for reflective online conversations: Models for online education* (pp. 75-101). Hershey, PA: IGI Global.

Mkrttchian, V., Stephanova G. (2013) Training of Avatar Moderator in Sliding Mode Control. In G. Eby & T. VokanYuzer (Eds.), *Project Management Approaches for Online Learning Design* (pp. 175-203). Hershey, PA: IGI Global.

Mkrttchian, V., Stephanova G. (2013) Training of Avatar Moderator in Sliding Mode Control Environment for Virtual Project Management. In J.A. Romero et al. (Eds.), *Enterprise Resource Planning: Concepts, Methodologies, Tools, and Applications*. (pp. 1376-1405). Hershey, PA: IGI Global.

Mkrttchian, V., Kataev M., Hwang W., Bedi S., Fedotova A. (2014). Using Plug-Avatars “HHH” Technology Education as Service-Oriented Virtual Learning Environment in Sliding Mode. In G. Eby & T. VokanYuzer (Eds.), *Emerging Priorities and Trends in Online Education: Communication, Pedagogy, and Technology*. Hershey, PA: IGI Global.

Mkrttchian, V. (2013). Training of Avatar Moderator in Sliding Mode Control Environment for Virtual Project Management. In *Enterprise Resource Planning: Concepts, Methodologies, Tools, and Applications* (pp. 1376-1405). Hershey, PA: IGI Global.

Mkrttchian, V. (2015). Modelling using of Triple H-Avatar Technology in online Multi-Cloud Platform Lab. In *Encyclopedia of Information Science and Technology* (3rd ed., pp. 4162-4170). Hershey, PA: IGI Global

Mkrttchian V., Aysmontas, B., Uddin, M., Andreev, A., Vorovchenko, N. (2015), The Academic views from Moscow Universities of the Cyber U-Learning on the Future of Online Education at Russia and Ukraine. In G. Eby, & T. VokanYuzer (Eds.), *Identification, Evaluation, and Perceptions of Online Education Experts* (pp. 32-45). Hershey, PA: IGI Global.

Mkrttchian, V., Bershadsky, A., Bozhday, A., & Fionova, L. (2015), Model in SM of DEE Based on Service Oriented Interactions at Dynamic Software Product Lines. In G. Eby, & T. VokanYuzer (Eds.), *Identification, Evaluation, and Perceptions of Online Education Experts* (pp. 230-247). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8119-4.ch014

Vardan Mkrttchian graduated from State Engineering University of Armenia, the Faculty of Cybernetics as an Electronics Engineer and received his Doctorate of Sciences (Engineering) in Control Systems from Lomonosov Moscow State University (former USSR). Dr. Vardan Mkrttchian taught for undergraduate and graduate student's courses of control system, information sciences and technology, at the Astrakhan State University (Russian Federation), where he was is the Professor of the Information Systems (www.aspu.ru) six years. Now he is full professor CAD and Economy departments of Penza State University (www.pnzgu.ru). He is currently chief executive of HHH University, Australia and team leader of the international academics (www.hhhuniversity.com). He also serves as executive director of the HHH Technology Incorporation. Professor Vardan Mkrttchian has authored over 400 refereed publications. He is the author of over twenty books published at IGI Global, included ten books indexed of SCOPUS in IT, Control System, Digital Economy, and Education Technology, and 41 works in SCOPUS and 15 in WoS. He also is Editor-in-Chief of International Journal of Applied Research in Bioinformatics (IJARB).

Leyla Gamidullaeva graduated from Penza State University, the Faculty of Economics and Management, getting qualifications of an economist. L. Gamidullaeva got her PhD in Economics from Penza State University of Architecture and Construction in 2010 followed by the title of associate professor in 2018. Now she is associate professor at the department of management and economic security of Penza State University. Currently, L. Gamidullaeva is doing her doctoral research in the regional innovation system management at St Petersburg State University. She has authored more than 200 refereed publications and over ten books in innovation management, regional economic growth, networking and collaboration.

Rinat Galiautdinov is a Principal Software Developer and Architect having the expertise in Information Technology and Computer Science. Mr. Galiautdinov is also an expert in Banking/Financial industry as well as in Neurobiological sphere. Mr. Rinat Galiautdinov works on a number of highly important research as an independent researcher.