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RECOGNITION OF CORONA DISCHARGE PRESENCE BY ACOUSTIC SYSTEM INSTALLED ON UNMANNED AERIAL VEHICLE

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Abstract

The energy complex of Ukraine still remains a rather powerful complex among the countries of the Eurozone. Ukrainian electrical networks, which are part of the energy complex, have significant branches. The length of high and ultra-high voltage power lines (750, 330, 220, 110 kV) is thousands of kilometers. Deterioration of equipment in the power supply system of Ukraine affects the reliability of power supply and quality indicators. In such conditions, maintenance of the operating condition of the equipment is provided by routine maintenance. Considerable attention is paid to the timely detection of damage, accurate determination of the accident site and its nature. High voltage in the network leads to the appearance of such a side factor as corona discharge, which not only consumes significant amounts of electrical energy, but also distorts it. The appearance of a corona discharge may indicate an electrical malfunction of the current transmission system. Therefore, the authors chose the direction of developing galvanically independent systems for diagnosing the state of power equipment through diagnosing the presence of a corona discharge. For determining the presence of a corona discharge, it is necessary to use either a significant number of diagnostic systems, or the location of such systems on mobile platforms. It is proposed to use unmanned aerial vehicles as a platform. The methods of acoustic control proposed by the authors can be blocked by the intrinsic noises of aircraft. Therefore, an acoustic analysis of various operating modes of aircraft was carried out and compared with the acoustic spectrum of a corona discharge. The obtained results made it possible to visualize the possibility of using acoustic systems on board unmanned aerial vehicles to diagnose corona discharge by acoustic parameters.

Keywords: power supply system; reliability; quality of electrical energy; unmanned aerial vehicles; UAVs; monitoring; Fourier transforms; acoustic signals

1. Introduction

The energy complex of Ukraine still remains a rather powerful complex among the countries of the Eurozone. Ukrainian electrical networks that are part of the structure of the energy complex have significant branching. In addition, the energy system of Ukraine has significant equipment wear. Therefore, in order to maintain it in operation, it is necessary to pay worthy attention not only to developed circuit connections, but also to pay attention to maintaining the reliability of the system, taking into account the wear of the equipment [1,2]. There is a list of energy objects that need constant monitoring. Therefore, in order to meet the requirements for diagnostics and monitoring the state of equipment, it is proposed to use unmanned aerial vehicles (UAVs) with monitoring and diagnostics systems on them [3,4].

Electrical systems are designed to carry high and ultra-high voltage currents, which represent significant barriers to the use of diagnostic equipment. High voltage leads to the appearance of such a side factor as corona discharge, which not only consumes significant amounts of electrical energy, but also distorts it [5,6]. The appearance of a corona discharge can also mean an electrical malfunction of the current transmission system. Therefore, the authors chose the direction of developing galvanically independent systems for diagnosing the state of power equipment, through diagnosing the presence of a corona discharge. The authors have developed acoustic methods for diagnosing the parameters of electrical systems, which makes it possible to carry out control actions without connecting to the network [7,8]. The article shows the possibility of using UAVs for acoustic measurements.

The purpose of the work is to develop approaches for electrical networks and energy systems servicing by acoustic methods and to demonstrate the possibility of using UAVs to achieve this goal with acoustic control systems installed on it.

2. Methods and means

Automation of the process of quality control of electrical energy requires the use of systems for automatic recognition of the presence of a corona discharge and determination of its coordinates. The length of high and ultra-high voltage power lines (750, 330, 220, 110 kV) is thousands of kilometers. Corona monitoring requires the use of either a significant number of diagnostic systems, or the location of such systems on mobile platforms [9].

The team of authors considers UAVs to be the most promising platform. Because in most cases, power lines are located in private territory or pass through territories that do not have roads for the movement of motor vehicles. UAVs can quickly move on the area and close to energy objects at distances sufficient for carrying out diagnostic actions.

Therefore, UAV that was chosen as a mobile platform for placing the diagnostic system.

At this moment there are two main UAV designs: aircraft and helicopter (quadrocopter) types. Each design has its own disadvantages and advantages [10, 11].

Thus, helicopter-type UAVs (quadcopters) are designed to inspect electrical elements near the operator. The distance can be up to 5 km. And this type of UAV can provide an accurate survey of structures and electrically conductive elements.

Aircraft-type UAVs have a longer range and high travel speeds, therefore, such drones are planned to be used for operational inspection and finding locations of damage to electrical equipment or lines.

Let's consider quadcopters on the possibility of using them to accommodate acoustic control equipment.

During operation, UAV engines and propellers generate acoustic vibrations that can interfere with acoustic measurements. For this, a drone (Fig.1) DJI Mavic Pro (Da-Jiang Innovations Science and Technology Co., China) was considered.

(a)

(b)

Fig. 1. DJI Mavic Pro: (a) – front view; (b) – top view

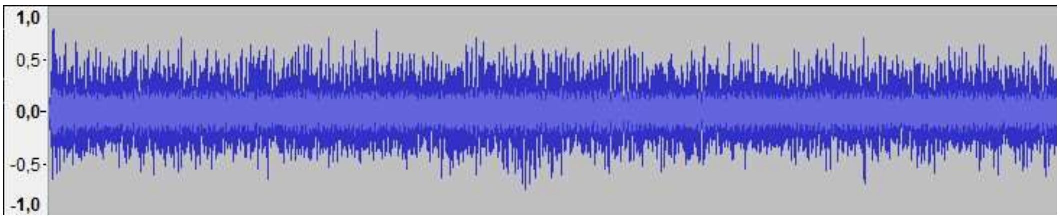
The operating time of this quadcopter is 30 minutes, action radius – to 7000 m. The UAV uses electric motors for movement, which rotate four rotors and provide vertical take-off and landing. The flight speed is up to 65 km/h. Dimensions (rolled up): 198 x 82 x 83 mm; weight – 0.74 kg; flight altitude – up to 5 km (programmatically limited to 120 m from the start point).

Takeoff weight is about 1 kg, payload is not more than 0.4 kg. Among the features of the device are its low price and an automatic return (landing) system. It's also equipped by video camera.

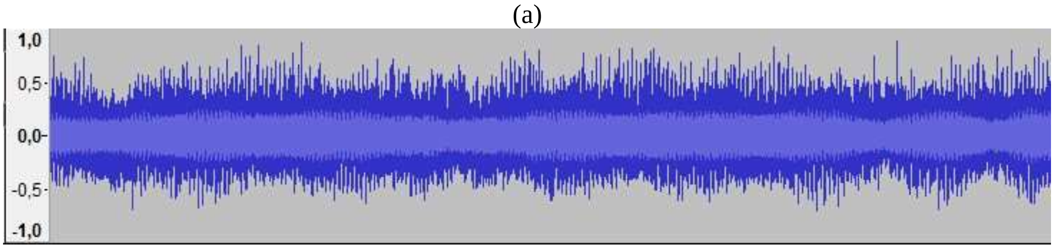
3. Results

For this quadcopter, sound files were recorded with different operating modes: takeoff, hang mode and flight. These basic modes of piloting a quadrocopter are needed during carrying out diagnostics of electrical systems [12].

Fragments of acoustic files of the drone piloting modes are shown in Fig. 2.



(a)



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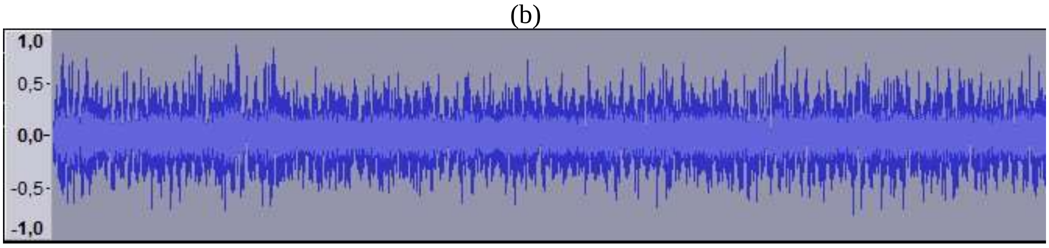
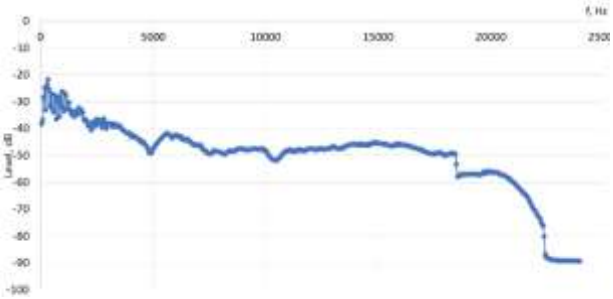


(c)

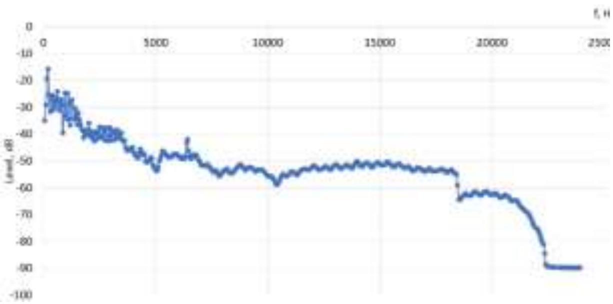
Fig. 2. Fragments of the acoustic file of the DJI Mavic Pro drone in different modes: (a) – takeoff, (b) – hang mode, (c) – flight

4. Discussion

Each of the specified audio files was analyzed for components of the acoustic spectrum (Fig. 3).



(a)



(b)

(c)

Fig. 3. Spectra of an acoustic file in different operating modes of the quadcopter: (a) – takeoff, (b) – hang mode, (c) – flight

Let us bring the spectral curves into one graph and compare them with the spectra of the corona discharge.

The enlarged spectral analysis (Fig. 4) shows that the spectral lines of the operating modes of the quadcopter engines overlap the spectral lines of the corona discharge.

Let’s consider the spectral functions in the range in which the spectral feature of the corona discharge is best appeared, and which obtained in practical measurements and chosen as a model for recognizing the corona discharge. This range is from 0 to 500 Hz. On this range, it can be seen the following (Fig. 5).

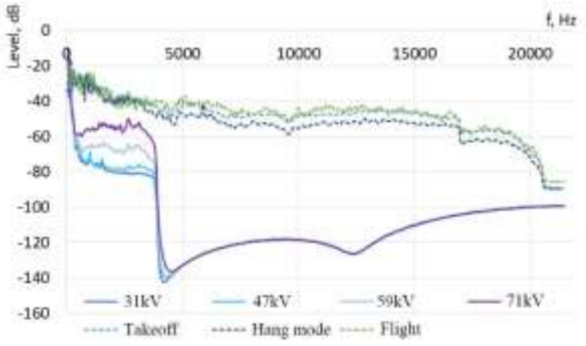


Fig. 4. Comparison of the spectra of operating modes of a quadcopter and different corona discharge powers

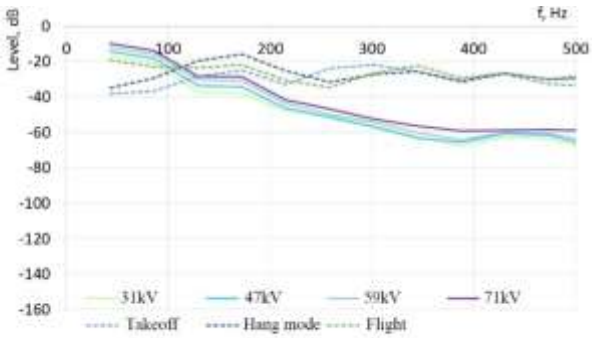


Fig. 5. Comparison of the spectra of a quadcopter and a corona discharge in the range of 0-500 Hz (FFT resolution 1024)

It can be seen that at ranges from 0 Hz to 150 Hz, the amplitudes of the corona discharge can exceed the amplitudes of the quadcopter engines.

With an increase in the detail of the spectral analysis, it was obtained the following image of the spectra distribution (Fig. 6).

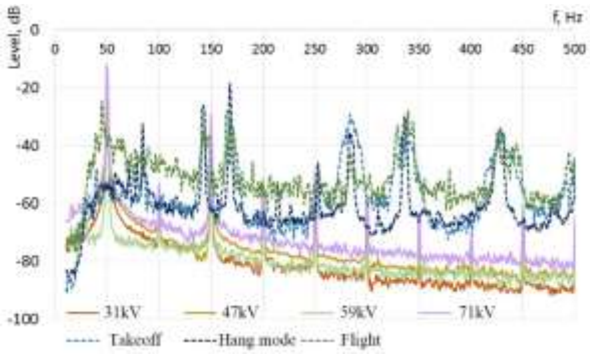
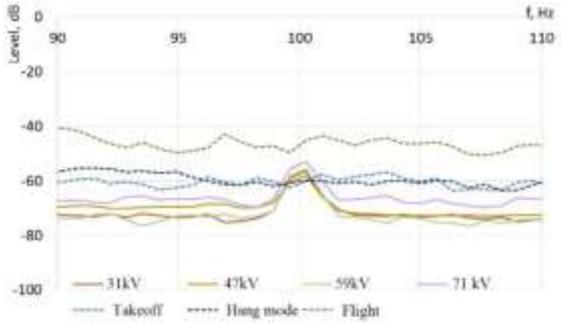
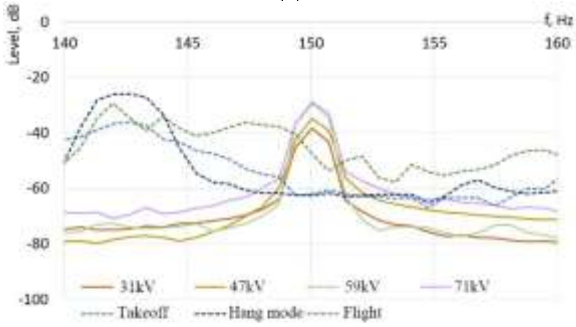


Fig. 6. Comparison of the spectra of a quadrocopter and a corona discharge in the range of 0-500 Hz (FFT resolution 65536)

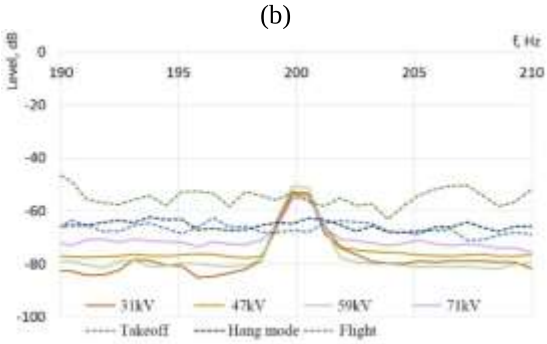
From Fig. 6 it can be seen that for some modes of quadcopter piloting, a situation is possible when the acoustic noise of the engines does not overlap the spectral peaks of the corona discharge. Fig. 7 shows detailed graphs of the acoustic spectra of the corona discharge and quadcopter engines.



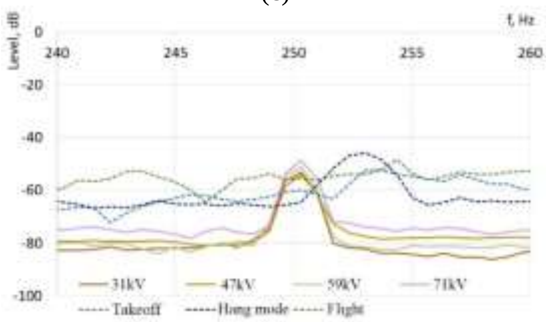
(a)



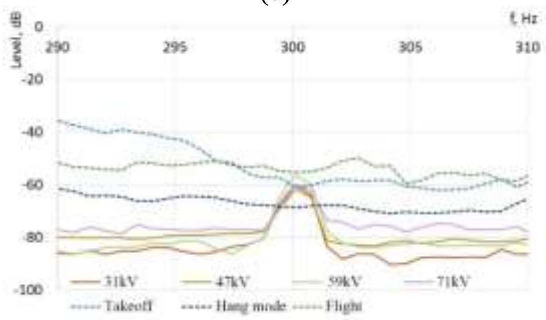
(b)



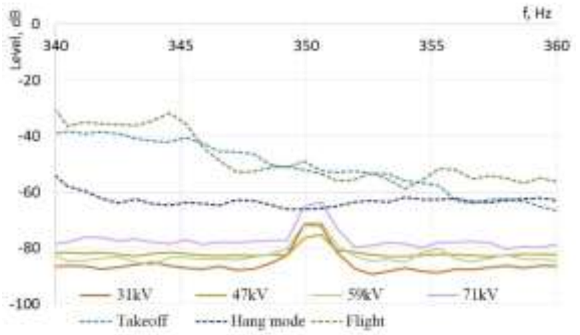
(c)



(d)



(e)



(f)

Fig. 7. Comparison of the spectra of a quadcopter and a corona discharge in the vicinity of: (a) – 100 Hz; (b) – 150 Hz; (c) – 200 Hz; (d) – 250 Hz; (e) – 300 Hz; (f) – 350 Hz

Obviously, during a quadcopter flight, the presence of a corona discharge can only be determined by some peaks, which are shown in Fig. 8.

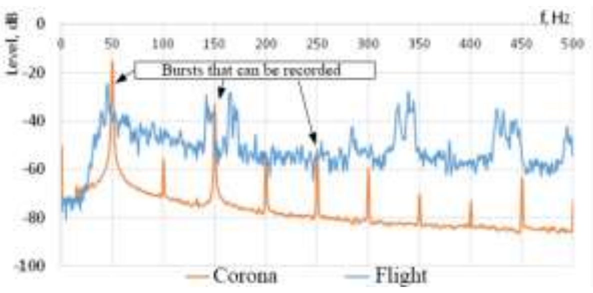


Fig. 8. Spectral peaks of corona discharge and acoustic spectrum of quadcopter engines during flight

But, during changing the piloting mode from flight to hang mode, the spectrum of the quadcopter changes, and in this case, more spectral peaks of the corona discharge can be determined (Fig. 9).

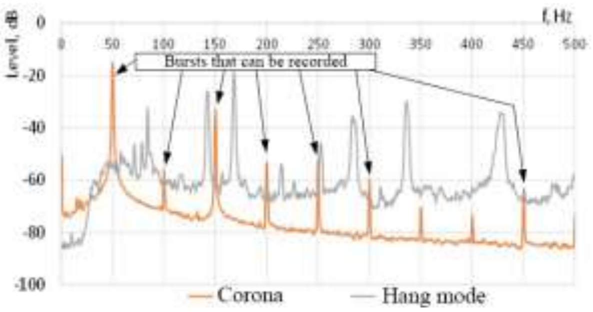


Fig. 9. Spectral peaks of corona discharge and acoustic spectrum quadcopter engines during hang mode

Thus, the possibility of installing the acoustic control system on a quadcopter is confirmed. But the procedure for determining the presence of a corona discharge will be as follows. Thus, during flight, the corona discharge can be determined only by two spectral components: 150 Hz and 250 Hz. Such detection of the corona discharge has a low accuracy, therefore, when such marker signals appear at certain frequencies, the quadcopter must switch to hang mode and check for peaks at frequencies of 100, 150, 200, 250, 300 Hz and, for example, 450 Hz. If the peaks at these frequencies with a width of no more than 2 Hz are present, it is possible to ascertain the localization of a corona discharge.

The results of spectral analysis confirmed the possibility of using the UAV as a platform for placing an acoustic control system.

4. Conclusions

To meet the requirements for maintaining the reliability of the energy system and ensuring the level of standardized indicators of the quality of electrical energy, it is necessary to increase the number of reviews of the energy system and introduce additional diagnostic equipment. It is proposed to use unmanned aerial vehicles as means of surface inspections. It is shown that it is possible to install acoustic contro and diagnostic equipment on the UAV, because the spectral characteristics of the diagnosed corona discharge do not overlap with the acoustic frequency spectrum of the UAV engine operation. In general, the use of UAVs will not only maintain the level of reliability, but also reduce the cost of maintaining the system. The authors consider the direction of research to be promising and will continue to work on the development of such systems.

References

[1] Using UAVs to improve the safety and efficiency of the energy system / Ye.I. Sokol, M.M. Rezynkina, O.H. Gryb and others; ed. by Sokol Ye.I. – Kharkiv: Brovin O.V., 2020. – 148 p. (in Ukrainian)

[2] Cost-effectiveness of monitoring power lines by unmanned aerial vehicles / Ye.I. Sokol, M.M. Rezynkina, O.H. Gryb and others; ed. by Sokol Ye.I. – Kharkiv: Brovin O.V., 2020. – 140 p. (in Ukrainian)

[3] Zaporozhets A. System for Monitoring the Technical State of Heating Networks Based on UAVs/ A. Zaporozhets, S. Kovtun, O. Dekusha // Advances in Intelligent Systems and Computing IV. - 2020. - vol. 1080. - pp. 935-950. doi: 10.1007/978-3-030-33695-0_61

[4] Kharchenko V., Kuzmenko N. Minimization of unmanned aerial vehicle trajectory deviation during the complicated obstacles overfly / V. Kharchenko, N. Kuzmenko // Proceedings of the

NAU. – 2012. – №2. – pp. 18-21

[5] Rezinkina, M.M., Rezinkin, O.L., Svetlichnaya, E.E. Electric field in the vicinity of long thin conducting rods / M.M. Rezinkina, O.L. Rezinkin, E.E. Svetlichnaya // Technical Physics. – 2015. - vol. 60. – pp. 1277-1283. doi: 10.1134/S1063784215090182

[6] Rezinkina M. Influence of corona on strike probability of grounded electrodes by high voltage discharges / M. Rezinkina, O. REzinkin, F. D'Alessandro, A. Danyliuk, G. Lisachuk, E. Sosina, E. Svetlichnaya // Journal of Electrostatics. – 2016. – 2016. – vol. 83. – pp. 42-51. doi: 10.1016/j.elstat.2016.07.005

[7] Rezinkina M. Control and Monitoring of Power Transmission Lines Condition over Wide Area with the Help of UAVs / M. Rezinkina, O. Rezinkin, I. Karpaliuk, V. Grabko // Proceedings of 2020 IEEE 7th International Conference on Energy Smart Systems (ESS), 12-14 May 2020, Kyiv, Ukraine. – pp. 172-175. doi: 10.1109/ESS50319.2020.9160150

[8] Gryb, O. Monitoring of quality indicators by acoustic method / O. Gryb, N. Zakharenko, I. Karpaliuk, N. Rudevich, S. Shvets // Bulletin of the National Technical University "KhPI". Ser. : Energy: reliability and energy efficiency. – 2019. – №29. – pp. 47-51. http://repository.kpi.kharkov.ua/handle/KhPI-Press/47310 (in Ukrainian)

[9] Babak, V.P. Principles of Construction of Systems for Diagnosing the Energy Equipment / V.P. Babak, S.V. Babak, M.V. Myslovych, A.O. Zaporozhets, V.M. Zvaritch // Diagnostic Systems For Energy Equipments. Studies in Systems, Decision and Control. - 2020. - vol. 281. - pp. 1-22. doi: 10.1007/978-3-030-44443-3_1

[10] Kortunov, V.I. Review and comparative analysyis of mini- and micro-UAV autopilots / V.I. Kovtunov, O.V. Mazurenko, A.V. Gorbenko, W. Mohammed, A. Hussein // Proceedings of 2015 IEEE International Conference Actual Problems of Unmanned Aerial Vehicles Developments (APUAVD), 13-15 Oct. 2915, Kiev, Ukraine. – pp. 284-289. doi: 10.1109/APUAVD.2015.7346622

[11] Deng, C. Unmanned Aerial Vehicles for Power Line Inspection: A Cooperative Way in Platforms and Communications / C. Deng, S. Wang, Z.Huang, Z. Tan, J. Liu // Journal of Communications. – 2014. – vol. 9. – №9. – pp. 687-692.

[12] Babak, S. Module structure of UAV-based computerized systems for remote environment monitoring of energy facilities / S. Babak, M. Myslovych, R. Sysak // Proceedings of 2016 17th International Conference Computational Problems of Electrical Engineering (CPEE), 14-17 Sept. 2016, Sandomierz, Poland. doi: 10.1109/CPEE.2016.7738752

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Розпізнавання наявності коронного розряду акустичним комплексом встановленим на безпілотному літальному апараті

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Енергетичний комплекс України досі залишається досить потужним комплексом серед країн Єврозони. Українські електричні мережі, що входять до енергетичного комплексу мають значне розгалуження. Протяжність ліній електропередач високої і надвисокої напруги (750, 330, 220, 110 кВ) налічують тисячі кілометрів. Зношеність обладнання в системі електропостачання Україні позначається на надійності електропостачання і на якісних показниках. В таких умовах підтримання робочого стану обладнання забезпечується поточним обслуговуванням. Значна увага приділяється своєчасному виявленню пошкодження, точному визначенні місця аварії і її характеру. Висока напруга в мережі призводить до появи такого побічного фактору, як коронний розряд, який не тільки споживає значні обсяги електричної енергії, але й спотворює її. Поява коронного розряду може бути ознакою електричної несправності системи передачі струму. Тому авторами було обрано напрям по розробці гальванічно-незалежних систем діагностики стану енергетичного обладнання через діагностику наявності коронного розряду. Для визначення наявності коронного розряду необхідно використання або значної кількості систем діагностики, або розташування таких систем на пересувних платформах. Пропонується використовувати безпілотні літальні апарати в якості платформи. Запропоновані авторами методи акустичного контролю можуть бути заблоковані власними шумами літальних апаратів. Тому було проведено акустичний аналіз різних режимів роботи літальних апаратів і їх порівняння із акустичним спектром коронного розряду. Отримані результати дозволили візуалізувати можливість використання акустичних систем на борту безпілотних літальних апаратів для проведення діагностики коронного розряду за акустичними параметрами.

Ключові слова: система електропостачання, надійність, якість електричної енергії, безпілотні літальні апарати, моніторинг, перетворення Фур'є, акустичні сигнали

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Распознавание наличия коронного разряда акустическим комплексом установленным на беспилотном летательном аппарате

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Энергетический комплекс Украины до сих пор остается достаточно мощным комплексом среди стран Еврозоны. Украинские электрические сети, входящие в энергетический комплекс, имеют значительные ветвления. Протяженность линий электропередач высокого и сверхвысокого напряжения (750, 330, 220, 110 кВ) насчитывает тысячи километров. Изношенность оборудования в системе электроснабжения Украине сказывается на надежности электроснабжения и на качественных показателях. В таких условиях поддержка рабочего состояния оборудования обеспечивается текущим обслуживанием. Значительное внимание уделяется своевременному выявлению повреждений, точному определению места аварии и ее характера. Высокое напряжение в сети приводит к появлению такого побочного фактора, как коронный разряд, который не только потребляет значительные объемы электрической энергии, но и искажает ее. Появление коронного разряда может быть признаком электрической неисправности системы передачи тока. Поэтому авторами было избрано направление по разработке гальванически-независимых систем диагностики состояния энергетического оборудования через диагностику наличия коронного разряда. Для определения наличия коронного разряда необходимо использование или значительного количества систем диагностики, или расположение таких систем на передвижных платформах. Предлагается использовать беспилотные летательные аппараты в качестве платформы. Предложенные авторами методы акустического контроля могут быть заблокированы собственными шумами летательных аппаратов. Поэтому был проведен акустический анализ различных режимов работы летательных аппаратов и их сравнение с акустическим спектром коронного разряда. Полученные результаты позволили визуализировать возможность использования акустических систем на борту беспилотных летательных аппаратов для проведения диагностики коронного разряда по акустическим параметрам.

Ключевые слова: система электроснабжения, надежность, качество электрической энергии, беспилотные летательные аппараты, мониторинг, преобразования Фурье, акустические сигналы

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