Light & Engineering
Vol. 27, No. 2, pp. 71–77, 2019 *https://doi.org/10.33383/2018-071*

POSSIBILITY OF USING IN RUSSIA THE EXPERIENCE OF LED LIGHTING APPLICATION AT THE USA AIRFIELDS

Vladimir V. Vorozhikhin*, Eugenia L. Moreva, Vladimir G. Starovoytov, and Igor G. Tyutyunnik

Financial University under the Government of the Russian Federation, Moscow
**Plekhanov Russian University of Economics, Moscow*
** E-mail: vorozhikhin@mail.ru*

ABSTRACT

The purpose of this paper is an investigation of LEDs illumination experience at US-based aerodromes with an assessment of its feasibility and its necessity in Russia.

The following methods were used: the analysis of aerodrome lighting requirements; the review and the analysis of development features in aerodrome LEDs illumination; the experience analysis of LEDs illumination of US-based aerodromes; the deductive analysis and the assessment synthesis of feasibility and necessity of US experience in LEDs illumination at Russian-based aerodromes.

The following results were achieved:

– The analysis of issues and opportunities was conducted for development of LEDs illumination at US-based aerodromes and of American experts' recommendations for its use;

– The cases were taken for use and assessment of development in LEDs illumination at US-based aerodromes;

– The review and the analysis were conducted in relation to a developing market of LEDs illumination at Russian-based aerodromes.

The main conclusion is that the US experience will improve quality and reliability of service provided in air transportation, comfort, and safety of Russian flights, as well as competitiveness of Russian-based airports and airlines (indirectly).

Keywords: LEDs illumination, airport network development, development features of aerodrome (airport) LEDs illumination, new market emergence for aerodrome (airport) LEDs illumination

1. INTRODUCTION

1.1. Aerodrome Lighting Requirements

The niche of air transportation in the international market of transport services is transportation of passengers, as well as of expensive, perishable, and hazardous goods, or of goods with small weight and dimensional values over long distances, with a high cost of payment per 1 kg of weight. Any non-scheduled delays, not to mention accidents and catastrophes, lead to significant and often irrecoverable damages [1]. That is why reliability of flight safety is so significant. Visual signals, including lighting equipment, are the most important part.

The aerodrome electrical lighting is included in the scope of airport activities [1, 2]. The international standards and the recommended practices are set out in the requirements for design and operation of aerodromes [2] and in the certification rules [3]. The system of visual lighting equipment includes:

- Funnel lighting system;
- Runway landing lights;
- Runway threshold lights;
- Runway end lights;
- Runway centre-line lights;
- Touchdown zone lights;
- Stop bars lights at taxi-holding points;

• Main taxi track lights and stop bars lights (excluding stop bars lights at taxi-holding points);
• Obstruction lights, etc.

The aerodrome lighting power network diagram is designed in such a way that, when a single section of the power network fails, the pilot does not lose any visual orientation and the luminance pattern does not become distorted. The properties of power networks for aerodrome lights and the rules for aerodrome lighting systems control are well known [2, 3].

Interacting with airlines, airports should provide comfort and safety of flights in accordance with the regulated service quality [4–6]. The importance of the infrastructure, which is a part of the aviation traffic safety system, requires its protection, which is governed by the airport security regulations (Decree of the Government of the Russian Federation dated 1 February 2011 No. 42 for Approval of the Security Rules for Airports and their Infrastructure).

In accordance with Article 48 of the Aviation Code of the Russian Federation [7], the equipment, including lighting equipment installed at civil aerodromes, joint civil/state aerodromes, and joint-use aerodromes, must meet the requirements for serviceability that are confirmed by an appropriate serviceability certificate [8, 9].

Multi-coloured lights (red, yellow, green, blue, and white signals) are used in US lighting systems, for which corresponding blackout curves are set (according to Engineering Brief No. 67D). White-yellow and red-yellow signal lights are used as well. The lights have various intensity rates: low (low-intensity lights), medium and high (high-intensity lights) [2, 3]. AC150/5340–30H provides replacement of three-stage regulators with a five-stage version. A variety of properties, as well as stiff requirements to luminance and reliability create the need for LEDs illumination and its intellectual management for airports. The narrow LEDs radiation spectrum also allows us to work with various optical systems, including infrared (IR) systems.

In addition to specified lights, the market sectors for LEDs illumination are lighting equipment of aircraft, buildings, structures, and environs [7]. Under such a use, LEDs become part of architectural and cultural design of modern airports. They ensure a comfortable stay of passengers in airport premises. They can support transmission of internet information with *Li-Fi* that allows for LEDs light to be used as an information carrier. Luminous carpets, being navigation and communication tools that show directions in multi-storey offices, airports, and shopping malls, are already widely used in the US. They feature arrows or text phrases to suggest directions for people and equipment. Smart light can provide security, transmit information about any accident or shot sounds to an appropriate service. Such a lighting system is already successfully operating not only at US-based airports, but also in streets of some cities (e.g. Los Angeles).

In Russia, for instance, integrated lighting systems are developed on the basis of street lights with Philips *RoadFlair* LEDs [10].

The need for development of home systems of electric and signal equipment in Russia was caused by rapid development of passenger flights and cargo flights in the 1970s and introduction of multi-seated jet aircrafts of the 2nd generation and of the 3rd generation such as TU-154, IL-62, IL-76, and IL-86. In 1971, the USSR joined the ICAO which developed standards and rules for unified properties and parameters of on-board equipment and ground equipment for flight operations at all weather conditions.

At that time, the airport equipment in the USSR did not meet the requirements of the ICAO, which significantly retarded development of international air transportation. Only few large airports were equipped with foreign equipment (from Czechoslovakia or Finland) which put civil aviation with joint air forces aerodromes (in particular cases) in a dangerous dependence on foreign suppliers [11].

The technical inferiority of Russia is repeated through a half of a century, demanding a strategic interaction of modern airport enterprises and airlines, innovative solutions (specifically, advanced LEDs illumination) to achieve competitiveness in the system of global air transportation [1].

1.2. Development of Smart LEDs Illumination Technologies for Airports

The advantages of LEDs illumination include the following: increased luminous efficacy, no hazardous substances, high durability features, extended service life, much smaller weight and size parameters [12–14].

In 2013–2016, a pilot project was implemented which introduced LEDs illumination at the largest international airport, PHL (Philadelphia, the US)

[15]. PHL employees, with the assistance of *GATEWAY* specialists from the US Department of Energy, first conducted a survey and an analysis of electrical energy consumption for lighting equipment in aircraft parking areas, apron areas, and passenger terminal areas. The expected energy savings reached almost 50 %.

The project implementation confirmed the calculations: the introduction of new lighting equipment allowed saving significant amounts of energy, optimizing the distribution of airport lighting levels for specific tasks of aircraft maintenance, ground equipment operation, passenger services, and flight safety [16, 17].

The practical use of new LED equipment prompted the Illuminating Engineering Society of North America (IESNA) to make changes to IESNA-RP-17–1987 (Airport Service Area Lighting) and IESNA-RP-14–1987 (Airport Road Automobile Parking Area Lights): they have been updated and merged into a single document, IES RP-37–15, which provides additional information on important advantages of LEDs illumination [18].

A brief overview of the standards of the Federal Aviation Administration of the United States (FAA) is given in [19] in terms of LEDs illumination and energy efficiency. FAA operations personnel controls lighting systems and visual indicators of approach flight tracks, and airport personnel controls runways, taxiways, and parking lights [20].

LEDs can provide enhanced colour rendering, which is important in determination of traffic route dye marking and, with high-efficient control devices, can switch on and off, instantly or gradually, at almost any temperature.

In December 2015, a 3 MW solar power plant was commissioned at the Minnesota International Airport (MSP) [21, 22]. During reconstruction and modernization of lighting equipment under the company's project on energy efficiency and renewable energy, 7,700 *Ameresco* halide lamps were replaced with energy-efficient LEDs which significantly reduced energy consumption. At the same time, this solar power plant currently provides almost 20 % of the total energy capacity for the airport, reducing greenhouse gas emissions by 6,813 tonnes per year. All this increases reliability and sustainability of airport lighting, saves significant amounts of energy, and allows them to build an airport lighting system with a high degree of independence from external sources of energy supply.

1.3. US-based Airports and Organizations that Explore LEDs Illumination Feasibility for Airport-associated Needs

There are about 5,000 US-based airports [23], 3,300 of which are part of the National Airports System and are eligible for federal development grants [25]. The Transportation Research Board (TRB), which offers innovative, research-based solutions to improve transport activities, is involved in air transportation development of the US. The TRB is jointly managed by the United States National Academy of Sciences, the United States National Academy of Engineering Sciences, and the United States Institute of Medicine.

<u>The objective of this work</u> is to study the experience of LEDs illumination at US-based aerodromes (airports) with an assessment of feasibility and necessity of LEDs illumination in Russia.

2. METHODS

Such scientific methods as analysis, synthesis, and deduction were applied during our study on modernization with an introduction of LEDs illumination at Russian airports based on the experience of the United States. The following analyses took place: the analysis of aerodrome lighting requirements; the review and the analysis of development features in aerodrome LEDs illumination; the experience analysis of LEDs illumination at US-based airports; the deductive analysis and the assessment synthesis of feasibility and necessity of the US experience in Russian LEDs illumination.

3. RESULTS

The aerodrome ground lighting (AGL) ensures visibility for runways and taxi tracks. Over the past decade, significant steps have been taken to support this activity at US-based aerodromes, and LEDs technologies have become more common in AGL (Figs. 1, 2).

Reconstruction of an AGL system requires development of high-quality project documentation. Acceptance testing and commissioning of AGL should be linked to each construction project and applicable regulations. In case of phased introduction of LEDs illumination, the issues of compatibility of LED lamps with existing energy infrastructure may arise at an airport. In order to ensure compatibility

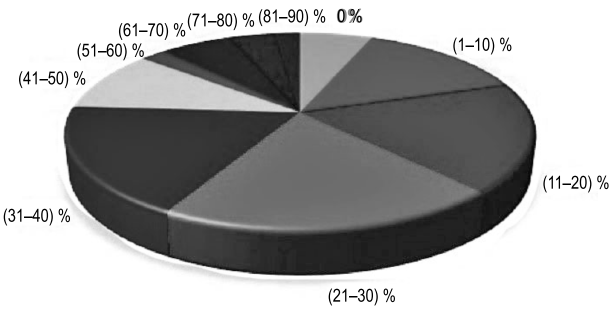

Fig. 1. The percentage for use of LED illumination devices at the surveyed aerodromes [25]

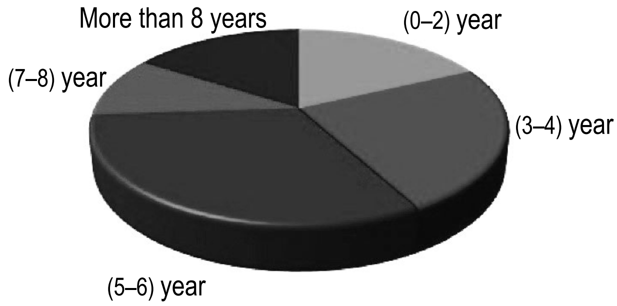

Fig. 2. The current duration for use of LEDs illumination at the surveyed aerodromes [25]

with existing equipment, design and installation of lamps should be coordinated [24].

Acceptance inspection of an aerodrome lighting system must include visual inspection and physical inspection of this system, electrical testing, photometric testing, and a systematic failure test [25].

LED lamps for various purposes (runway edge lights, runway centre-line lights, taxiway lights, obstruction lights, touchdown zone lights, lift-off zone lights, runway identification threshold lights, aerodrome signs, etc.) are used in various proportions in AGL [25].

Visual check identifies compliance of orientation and physical condition (including integrity and purity) with an energy supply system design (1 level, 3 levels, or 5 levels). It is recommended to check a 20 % random sample of lamps. If a defect is found, other 20 % of lamps should be opened and checked. All defective lamps should be repaired and rechecked.

Electrical testing ensures that minimum specified standards are met and provides basic data for service management. Circuit insulation resistance measurement (50 MΩ, according to AC150/5340–30H) ensures no current losses and is used to analyse dynamic properties of insulation processes and use environment. Measurements of impedance and power of system load should be carried out at regular intervals. Electrical equipment is non-resistant to dust and dirt which specifically contribute to overheating and premature failure of lamps.

Photometric testing (with lamps commissioning) includes standard photometric measurements that correspond to the type (purpose) of the tested lamp.

A systemic failure test allows you to detect substandard components (electronic components as a source of failure) during sweeping or so called burn-in. It is recommended to use a sweep period that is 5–10 times longer than the normal daily operating period which is usually 12 hours.

The system of acceptance tests is important for inventory management of lighting assets and for lighting system savings. The recommended warranty period is 4 years according to AC150/5345–43H, and the lamp replacement criteria are according to AC150/5340–26C. Airports should also check lamps at least twice a month. Lamps may have a higher failure rate due to vibration in the middle of the runway, on taxiways, or in touchdown zones. Modern LED lamps are much more reliable than their predecessors, requiring a much lower frequency of replacements. To manage warranty obligations, it is necessary to specify a lamp installation date and to develop a post-warranty strategy (e.g. including a service contract, an extended warranty period, or internal repair work).

The problem is equipment obsolescence due to rapid development of LED technologies, especially for small airports which cannot often receive any support from the FAA. The obsolescence problem is partially mitigated by adaptive electronics.

The typical empirical rule for spare parts is their 10 % share from the design quantity. However, with due regard to LEDs longevity, it can be reduced to 5 % (which also indicates LEDs advantage).

The savings of LEDs illumination depends on technical and operational properties of LED equipment. Decrease in expected operating costs for aerodrome LEDs illumination is confirmed by reduction in maintenance costs and a decrease in energy consumption of LED lamps.

Long-term operation (over 100,000 hours of continuous operation) is the main advantage of LED lamps that contain electrolyte-free capacitors in high-durable aluminium shells. At the same time, costs of special equipment are reduced (no crane trucks required for service of lamps up to 50 meters high).

4. DISCUSSION AND CONCLUSION

The article includes:

– The analysis of aerodrome lighting requirements, development features of aerodrome LEDs illumination, and experience of LEDs illumination at US-based aerodromes;

– The deductive analysis and the assessment synthesis of feasibility and necessity of the US experience in LEDs illumination of Russian-based aerodromes.

There is the number of on-line tools to compare estimated life-cycle values of various lighting systems [26], including in Russia:

1. The US Department of Energy (DOE) presents several methods to calculate energy savings and necessary costs for reconstruction of airport lighting systems (URL: http://www1.eere.energy.gov/femp/technologies/eep_eccalculators.html);

2. The New York State Energy Research and Development Authority (NYSERDA) offers an electronic worksheet to calculate life-cycle costs of commercial lighting systems. This worksheet can be adapted to estimate aerodrome lighting costs (URL: http://www.nyserda.ny.gov/Page-Sections/Business-Partners/Commercial-Lighting/Ток-Partners.aspx);

3. *General Electric Lighting* provides a number of simple tools to estimate energy costs and life-cycle costs (URL: http://www.gelighting.com/na/business_lighting/ education_resources/tools_software/toolkit);

4. The manufacturer of aerodrome lighting equipment, *ADB Airfield Solutions*, provides a tool for work with electronic worksheets to assess investment profitability and life-cycle costs for a number of types of LED illumination devices.

LEDs illumination costs became the greatest concern for personnel at the surveyed airports [25]. About 75 % of specialists said that LEDs illumination costs are a main barrier for aerodrome LEDs illumination. However, there is evidence that LEDs illumination, which is currently installed at aerodromes, provides (20–50)% of their general lighting in the majority of US-based airports [25]. Understanding the return on investment (ROI) required for adoption of LED technology helps decision makers select the best action plan for modernization of their airports. It is advisable to determine landing fees amounts for airlines at every aerodrome, with due regard to cost recovery for introduction of modern LEDs illumination [26, 27].

The following can be concluded based on the materials of the article:

• The state of the art for aerodrome (airport) LEDs illumination in Russia is lower than in the US;

• The experience of this LEDs illumination technology in the US is of undoubted interest for Russia since many of solved problems in the US can be taken into account when modernizing lighting systems of Russian airports;

• Russian organizations and institutions in fields of science, innovation, and operation of high-end equipment should participate in cross-professional discussion of various issues, and the scientific publications of the US, including the reports of the National Academy of Sciences of the United States, can be used to enhance this process;

• The US experience will improve quality and reliability of services provided in air transportation, comfort, and safety of Russian flights, as well as competitiveness of Russian-based airports and airlines (indirectly);

• It is advisable to use on-line tools in Russia that are recommended by US specialists to estimate life-cycle costs for LED lamps, with due regard to existing geographical and climatic factors.

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Vladimir V. Vorozhikhin, Ph. D. in Economics, graduated from the Moscow Power Engineering Institute (MPEI) in 1979. He is the Leading Researcher of the Centre for Monitoring and Evaluation of Economic Security under the Institute for Economic Policy and Economic Security Issues at the Financial University

Eugenia L. Moreva, Ph. D. in Economics, graduated from the Lomonosov Moscow State University, faculty of economics. She is the Deputy Director of the Institute of Industrial Policy and Institutional Development at the Financial University. Her Research interests are innovation economics, regional integration, and intellectual capital

Vladimir G. Starovoytov, Doctor of Economics, graduated from the Moscow Aviation Institute (1979) and the Russian Academy of National Economy and Public Administration (2000). He is the Director of the Centre for Monitoring and Evaluation of Economic Security under the Institute for Economic Policy and Economic Security Issues at the Financial University. His research interests include strategic planning and management, economic security, contracting development in government and municipal procurement

Igor G. Tyutyunnik, lawyer, graduated from the Moscow New Law Institute, faculty of law. He is the researcher of the Institute of Industrial Policy and Institutional Development at the Financial University. His research interests include industrial policy, innovation activity, and economic crime