Journal of Modern Energy Research
Vol. 1, No. 1, Dec 2023, pp. 27-32
ISSN: 3078-3534, DOI: 10.56947/jmer.v1i1.1

Voltage Deviation Influence on Electric Sizes of Lighting Lamps

Shahnoza Shonazarova[1], Saidjon Sheralievich Tavarov[1], Aleksandr Ivanovich Sidorov[1]
[1] Polytechnic Institutes, Department of Life Safety, South Ural State University (National Research University), Russia

Article Info

Article history:

Received Oct 4, 2023
Revised Nov 14, 2023
Accepted Nov 25, 2023

Keywords:

Rated voltage
Electrical quantities
Lighting lamps
Illumination
Active power factor

ABSTRACT

The influence of voltage deviation from the nominal value of 220 V on the illumination of incandescent lamps and high-pressure sodium lamp (HPSL) is presented. It has been established that voltage deviations from the nominal value do not affect the illumination of energy-saving and light-emitting diode (LED) lamps. It is shown that most of the energy-saving LED and HPSL lamps used in household and street lighting in Dushanbe have a low active power factor, which, in turn, leads to an increase in reactive power consumption in the electrical network.

Corresponding Author:

Shahnoza Shonazarova
Polytechnic Institute, Department of Life Safety
South Ural State University (National Research University)
454080 Chelyabinsk, Lenin Avenue, 76, Russia
Email: shonazarova87@inbox.ru

1. INTRODUCTION

According to the analysis of the causes of violations in urban electrical networks and the condition of electrical equipment, more than half of the equipment installed in 6-10/0.4 kV networks has a low power supply reliability indicator. It is known that voltage deviations affect the indicators of the reliability of power supply in urban distribution networks [1]-[5]. Especially in the winter period, there are strong voltage deviations from the nominal values in the distribution networks 6-10/0.4 kV in Dushanbe. Voltage deviations are known to have a significant effect on the illumination of incandescent lamps. Whereas on energy saving and LED lamps, voltage deviations have little effect on illumination [6]-[14]. To save energy, consumers in Dushanbe switched to energy-saving and LED lamps. The street lighting of the city of Dushanbe was transferred to the lighting type high-pressure sodium lamp. According to the data received from JSC "City Light", the total number of HPLS installed for street lighting in the city of Dushanbe exceeds the number of 15 thousand pieces. Voltage deviations from the nominal value have a significant effect on the illumination of these types of lighting lamps [15]-[16].

It is also necessary to note the following factor that the increase in voltage from the nominal value in the end affects the consumption of electricity, both in the distribution and in the general electrical network [17]-[21].

2. RESEARCH METHOD

To assess the effect of voltage deviation on the electrical values of lighting lamps on the developed universal laboratory bench of the Department of Power Supply, Tajik Technical University named after Acad. M.S. Experiments were carried out by Osimi. A universal laboratory stand allows you to study the lighting and electrical characteristics of incandescent lamps, modern energy-saving compact fluorescent, LED and lamp types, sodium arc tube and mercury arc lamps, mainly used for street lighting.

During the experiments, the voltage varied within (–14%, + 5%) of the nominal value. To account for electrical quantities, a universal measuring device OMIX P94-MX was used, which allows measuring the following parameters:

P - Active power, W;
Q - Reactive power, Var;
S - Apparent power, VA;
I - current, A;
Cos φ - active power factor;
F – frequency, Hz.
DT-1309 light meter was used to measure the illumination of the lighting lamps.
DT-1309 specifications:
Operating temperature –20… + 50 ° C;
Measurement range 0 ... 100000 Lx;
Resolution 1 Lx / 0.1Hz;
Measurement error 5%.

A laboratory autotransformer (LATR) was used to increase and decrease the voltage. The voltage at the terminals of the lighting lamps varied in the aisles from +230 V to –190 V with a step of ± 10 V.

3. RESEARCH RESULTS AND DISCUSSION

The results of experiments on the estimates of the influence of voltage deviation on the illumination and electrical values of incandescent, energy-saving, LED and HPSL are given (Table 1.2).

Table 1. Influence of voltage deviation on LED and incandescent lamps

Physical parameters	Incandescent lamp					6W LED lamp				
U, V	190	200	210	220	230	190	200	210	220	230
I, A	1,21	1,25	1,28	1,32	1,36	0,08	0,081	0,084	0,09	0,093
P, W	233	250	266	274	309	4,4	4,56	5,05	5,48	5,80
Q, Var	32	43	45	47	49	13,95	14,95	17,30	18,50	20,55
S, VA	236	254	270	278	315	14,35	15,87	17,60	19,80	21,65
Cos φ	0,98	0,99	0,99	0,99	0,99	0,33	0,30	0,29	0,29	0,28
E, Lx	515	642	785	896	1047	138	136	138	133	138

Table 2. Influence of voltage deviation on energy saving and high-pressure sodium lamp

Physical parameters	High-pressure sodium lamp -250					Energy saving lamp (30W)				
U, V	190	200	210	220	230	190	200	210	220	230
I, A	1,13	1,20	1,29	1,33	1,45	0,184	0,189	0,189	0,192	0,185
P, W	198	215	244	261	297	25,84	26,84	28,34	28,84	28,84
Q, Var	95	108	130	140	160	25,50	26,50	29,00	30,60	31,43
S, VA	217	240	274	310	330	35,44	37,35	40,00	42,14	42,25
Cos φ	0,91	0,91	0,90	0,92	0,91	0,74	0,74	0,71	0,70	0,70
E, Lx	1777	2030	2310	2720	3160	200	220	236	244	246

Table 1.2, the dependences of the influence of voltage changes on changes in current, active, reactive and total power (Figure 1-4), as well as on the illumination and active power factor of lighting lamps (Figure 5-6).

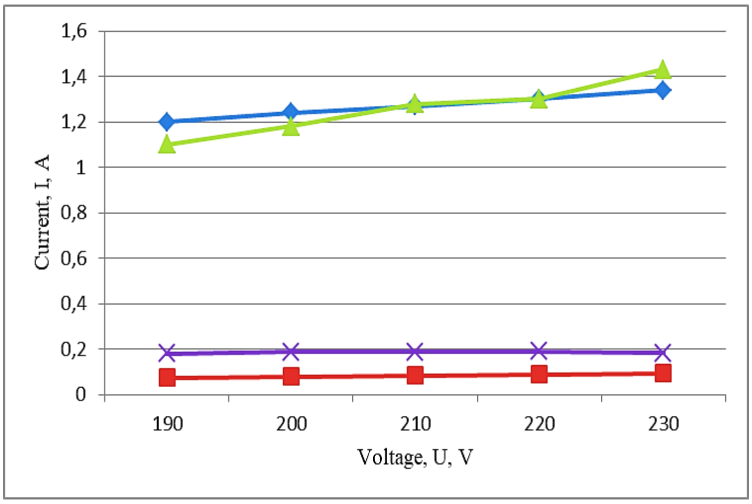

Figure 1. The influence of voltage changes on the current of lighting lamps

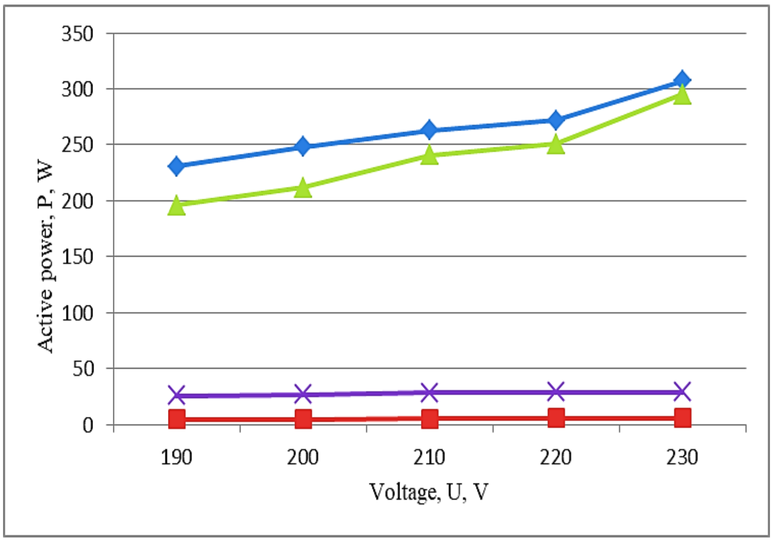

Figure 2. The influence of voltage changes on the active power of lighting lamps

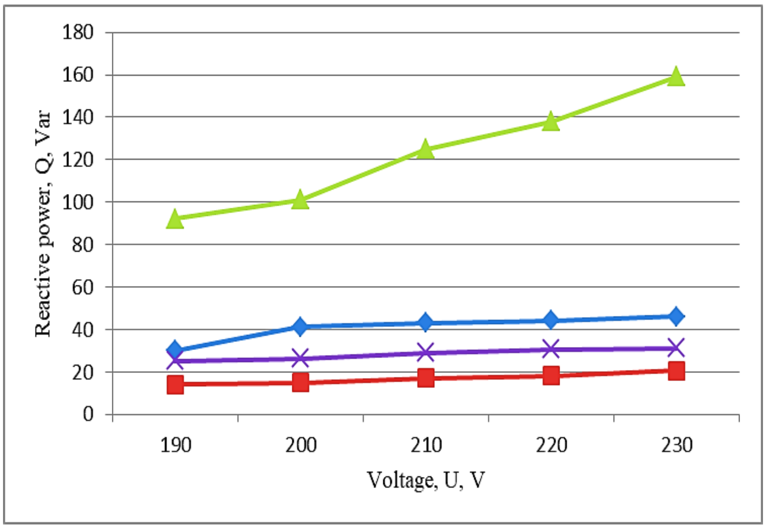

Figure 3. The influence of voltage changes on the reactive power of lighting lamps

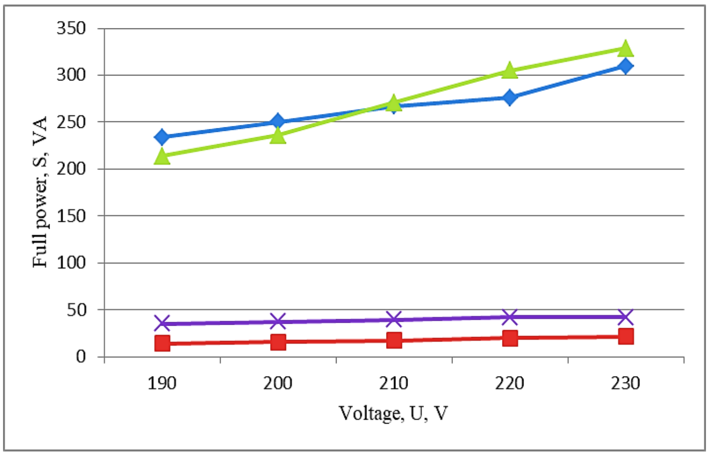

Figure 4. Effect of voltage variation on the full power of lighting lamps

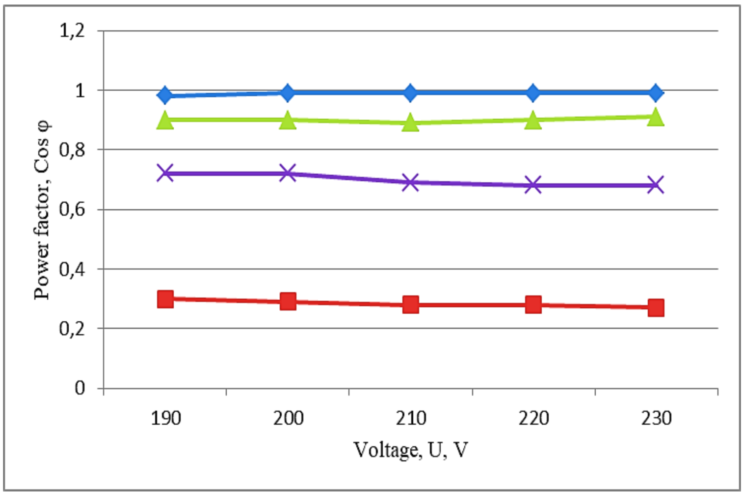

Figure 5. Influence of voltage changes on the power factor of lighting lamps

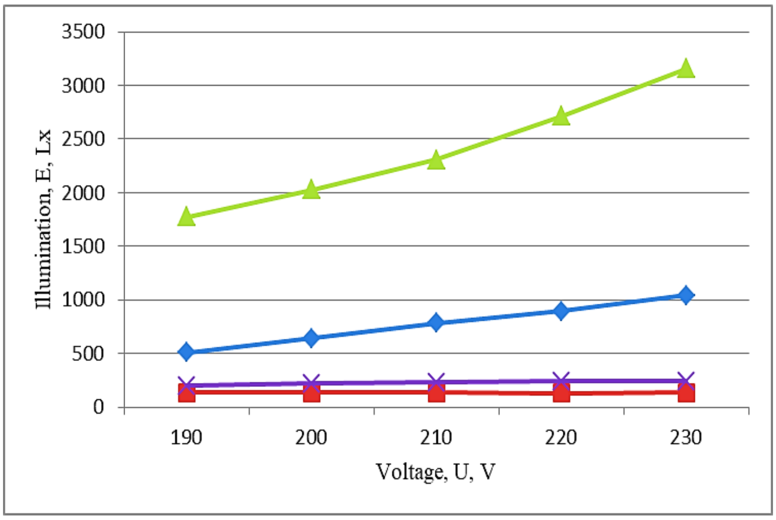

Figure 6. Effect of voltage changes on illumination of lighting lamps

According to (see Table 1,2) and (see Figure 6) when the voltage drops by (-14%, 190 V) from the nominal value, the illumination of incandescent lamps decreases by (-43%). Whereas when increasing by (+ 5%, 230 V), the illumination of the lamps increases by (+ 17%). The same picture is observed for arc high-pressure sodium lamp, a voltage decrease by (-14%, 190 V) reduces the illumination of lamps by (-35%), an increase in voltage by (+ 5%, 230 V) increases the illumination of lamps by (+ 16%).

For energy-saving and LED lamps, the increase in voltage by (+ 5%) does not particularly affect the illumination. When the voltage is lowered by (-14%), the illumination is reduced by (-17%).

As noted above for street lighting in Dushanbe, all lighting lamps were re-installed on high-pressure sodium lamp. To save energy for household consumers, most of the consumers have switched to energy-saving and LED lamps. From the obtained experimental results (see Table 2) it can be seen that voltage deviations do not affect the active power factor of high-pressure sodium lamp (see Figure 5). But regardless of this factor, these types of lamps have a low active power factor, which, as a result, affects an increase in current consumption, active, reactive and apparent power (see Figure 1-4).

Whereas on energy-saving and LED lamps, voltage deviations have a significant effect not on illumination, but on electrical quantities [22]-[33].

Thus, according to the experimental results obtained (see Table 1, 2), voltage deviations from the nominal values at the terminals of energy-saving and LED lamps have a very strong effect on the active power factor (see Figure 5). As a result, it leads to an increase in consumption of not only current and active power (see Figure 2) but also reactive power (see Figure 3). The reactive power value due to the low active power factor is several orders of magnitude greater than the active power (see Table 1.2).

When the voltage at the terminals of the LED lamp (-14%, 190 V) falls from the nominal value, the reactive power exceeds the active power by 3.2 times. With an increase of (+ 5%, 230 V), the reactive power exceeds the active power by 3.6 times (see Table 1).

For energy-saving lamps, when the voltage drops by (-14%, 190 V) from the nominal value, the reactive power is equal to the active power; when the voltage is increased by (+ 5%, 230 V), the reactive power exceeds the active power by 1.1 times.

It should be noted that out of 32 substations with voltages of 35 kV and above, which are in the balance of the urban electrical network of the city of Dushanbe, most of them lack compensating devices.

4. CONCLUSIONS

As a result, we can conclude that this problem is relevant for the city of Dushanbe. Since an increase in reactive power consumption leads to loading of electrical networks, an additional decrease in voltage and a decrease in the reliability of both urban distribution networks and the electrical network in general.

REFERENCES

[1] Cho, K., Oh, W., Yeon, J., Kim, D., Kim, H. Electronic ballast of the electrode-less lamp for the group lighting system. International Conference on Electrical and Electronics Engineering – ELECO, I-293- I-296, 2009. https://10.1109/ELECO.2009.5355257

[2] Cole, M., Martin, K. Lighting, light sources, economics and safety. Petroleum and Chemical Industry Conference Europe Electrical and Instrumentation Applications, 1-6, 2011

[3]. Tang, Y., Chen, Q., Ju, P., Jin, Y., Shen, F., Qi, B., Xu, Z. Research on load characteristics of energy-saving lamp and LED lamp. IEEE International Conference on Power System Technology (POWERCON), 2016, https:// 10.1109/POWERCON.2016.7753932

[4]. Mrabet, B. M., Chammam, A. M., Nsibi, W. Experimental Study of Electrical and Harmonics Characteristics of LED Bulbs and Comparison with Different Other Lamp-Ballast Systems. 15th International Multi-Conference on Systems, Signals & Devices (SSD), 2018, https:// 10.1109/SSD.2018.8570556

[5]. Renugadevi, R., Manoharan, P.S. Analysis of EOT characteristics of LED lamps. International Conference on Advances in Electrical Engineering (ICAEE), 2014, https:// 10.1109/ICAEE.2014.6838449.

[6]. Ogunjuyigbe, A. S., Ayodele, T. R., Idika, V. E. Olorunfemi Ojo. Effect of lamp technologies on the power quality of electrical distribution network. IEEE PES PowerAfrica, 2017, https:// 10.1109/PowerAfrica.2017.7991216

[7]. Yan, W., Hui, S. Y. R., Shu-Hung Chung, H. Energy Saving of Large-Scale High-Intensity-Discharge Lamp Lighting Networks Using a Central Reactive Power Control System. IEEE Transactions on Industrial Electronics, 56(8), 3069– 3078, 2009, https:// 10.1109/TIE.2009.2022089

[8]. Mucklejohn, S. A. An Overview of the Impact of Dimming Metal Halide Discharge Lamps. IEEE Transactions on Industry Applications, 51(6), 4797 – 4801, 2011, https:// 10.1109/TIA.2015.2445814

[9]. Collin, Adam J., Djokic, Sasa Z. J., Drapela, R. Langella, A. Testa. Light Flicker and Power Factor Labels for Comparing LED Lamp Performance. IEEE Transactions on Industry Applications 55 (6), 7062 – 7070, 2019, https:// 10.1109/TIA.2019.2919643

[10]. Wilde, M.B. Application of high-efficiency light sources. Engineering Science and Education Journal, 2 (2), 53 – 61, 1993, https:// 10.1049/esej:19930019

[11]. Yan, W., Hui, S.Y. An analysis into the dimming control and characteristic of discharge lamps, IEEE Transactions on Power Electronics, 20 (6), 1432 – 1440, 2005, https:// 10.1109/TPEL.2005.857507

[12]. Feng, W., He, Y., Shi, Frank G. Investigation of LED Light Output Performance Characteristics Under Different Alternating Current Regulation Modes. IEEE Journal of Selected Topics in Quantum Electronics 17(3), 720 – 723, 2011, https:// 10.1109/JSTQE.2011.2105859

[13]. Nascimento, C. B., Perin, A. J. High Power Factor Electronic Ballast for Fluorescent Lamps With Reduced Input Filter and Low Cost of Implementation. IEEE Transactions on Industrial Electronics, 55(2), 711 – 721, 2008, https:// 10.1109/TIE.2007.908536

[14]. Gluskin, E., Tsirbas, E., Kateri, I., Topalis, F. V. Use of logarithmic sensitivity in power system analysis: the example of lighting circuits (hot filament, LED and fluorescent lamp circuits). IET Science, Measurement & Technology, 7 (6), 297- 305, 2013, https:// 10.1049/iet-smt.2012.0124

[15]. Sidorov, A.I., Tavarov, S.S. Method for forecasting electric consumption for household users in the conditions of the Republic of Tajikistan. International Journal of Sustainable Development and Planning, Vol. 15, 4, 569-574, 2020, https://doi.org/10.18280/ijsdp.150417

[16]. Sidorov, A.I., Khanzhina, O.A., Tavarov, S.S. Ensuring the Efficiency of Distribution Networks C. Dushanbe and Republic of Tajikistan. International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon) 2019. http://dx.doi.org/10.1109/FarEastCon.2019.8934377.

[17] A. Zeghoudi, A. Bendaoud, G. Zissis, A. Tilmatine and L. Canale, "Experimental Measurements of Near Electric Field for AC/DC LED Lamp," *2023 IEEE Sustainable Smart Lighting World Conference & Expo (LS18)*, Mumbai, India, 2023, pp. 1-6, doi: 10.1109/LS1858153.2023.10170068.

[18] V. Gyurov and T. Dimitrov, "Analysis of the Photobiological Impact of LED Light Sources in the Context of Standardization Requirements for Reduction of Blue Light Emission," 2023 18th Conference on Electrical Machines, Drives and Power Systems (ELMA), Varna, Bulgaria, 2023, pp. 1-4, doi: 10.1109/ELMA58392.2023.10202372.

[19] W. Kaiser and R. P. Marques, "External Electrode Fluorescent Lamp (EEFL) Driving Methods," in IEEE Transactions on Industry Applications, vol. 55, no. 5, pp. 5429-5435, Sept.-Oct. 2019, doi: 10.1109/TIA.2019.2918045.

[20] B. Caillier, S. Belouadi, A. Belasri, K. Abdelbacet and N. L. D. Bachir, "Electrical behavior of an excimer lamp excited by an Argon-based dielectric barrier discharge," 2021 Joint Conference - 11th International Conference on Energy Efficiency in Domestic Appliances and Lighting & 17th International Symposium on the Science and Technology of Lighting (EEDAL/LS:17), Toulouse, France, 2022, pp. 1-3.

[21] Å. Wisten, "Impact of Lightning on Street Lights : - An experimental study investigating different poles and cables," 2020 International Symposium on Electromagnetic Compatibility - EMC EUROPE, Rome, Italy, 2020, pp. 1-7, doi: 10.1109/EMCEUROPE48519.2020.9245737.

[22] M. A. Ismeil, Y. B. Hassan, M. Orabi, A. Alshareef and H. S. Hussein, "Fulfill Optimum Calibrated Size of LED Driver Components for Solar Street Lighting Fixture by Adjusting the LEDs Connections," in IEEE Access, vol. 11, pp. 46832-46846, 2023, doi: 10.1109/ACCESS.2023.3275202.

[23] P. Hovorov, M. Khvorost and A. Kindinova, "Increasing the Efficiency of Lighting Objects in the Urban Environment," 2023 Eight Junior Conference on Lighting (Lighting), Sozopol, Bulgaria, 2023, pp. 1-5, doi: 10.1109/Lighting59819.2023.10299451.

[24] C. E. Ngene, P. Thakur and G. Singh, "Visible Light Communication-LEDs Illuminations for Smart Homes," 2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD), Durban, South Africa, 2020, pp. 1-5, doi: 10.1109/icABCD49160.2020.9183871.

[25] N. Trivellin et al., "Solid State Lighting for horticolture: impact of LED reliability on light spectrum and intensity," 2023 IEEE Sustainable Smart Lighting World Conference & Expo (LS18), Mumbai, India, 2023, pp. 1-5, doi: 10.1109/LS1858153.2023.10170252.

[26] J. MA et al., "Optimization control method for office lighting," 2020 Chinese Automation Congress (CAC), Shanghai, China, 2020, pp. 7359-7364, doi: 10.1109/CAC51589.2020.9327313.

[27] N. Gupta and D. Verma, "A Review and Analysis of Topologies of Light Emitting Diode (LED) Drivers," 2021 IEEE 2nd International Conference On Electrical Power and Energy Systems (ICEPES), Bhopal, India, 2021, pp. 1-6, doi: 10.1109/ICEPES52894.2021.9699637.

[28] "American National Standard for Methods of Measurement of Radio-Frequency Emissions from Lighting Devices," in ANSI/USEMCSC C63.29-2022 , vol., no., pp.1-205, 31 May 2023, doi: 10.1109/IEEESTD.2023.10137415.

[29] S. Bruno et al., "Fast Frequency Support Through LED Street Lighting in Small Non-Synchronous Power Systems," in IEEE Transactions on Industry Applications, vol. 59, no. 2, pp. 2277-2287, March-April 2023, doi: 10.1109/TIA.2022.3223964.

[30] A. Sureshkumar and R. Gunabalan, "Design of Robust Guaranteed Margin Stability Region PI Controller for Automotive LED Lighting With Parameter Uncertainty," in IEEE Access, vol. 10, pp. 15657-15670, 2022, doi: 10.1109/ACCESS.2022.3146392.

[31] A. N. Padmasali and S. G. Kini, "Accelerated Testing Based Lifetime Performance Evaluation of LEDs in LED Luminaire Systems," in IEEE Access, vol. 9, pp. 137140-137147, 2021, doi: 10.1109/ACCESS.2021.3118106.

[32] M. Esteki, D. Darvishrahimabadi, M. Shahabbasi and S. A. Khajehoddin, "An Electrolytic-Capacitor-Less PFC LED Driver With Low DC-Bus Voltage Stress for High Power Streetlighting Applications," in IEEE Transactions on Power Electronics, vol. 38, no. 5, pp. 6294-6310, May 2023, doi: 10.1109/TPEL.2023.3236013.

[33] S. Baik et al., "Conformal and Ultra Shallow Junction Formation Achieved Using a Pulsed-Laser Annealing Process Integrated With a Modified Plasma Assisted Doping Method," in IEEE Access, vol. 8, pp. 172166-172174, 2020, doi: 10.1109/ACCESS.2020.3024636.