# Energy Efficiency and Power Indicators of Household Lighting Devices Analysis

MARIA CHEREPANOVA, ALEXANDER EGOROV, EGOR LYUKHANOV, MARIA POSPELOVA
Automated Electrical Systems Department
Ural Federal University
19, Mira Street, Yekaterinburg
RUSSIA
cherepanovamari@gmail.com    http://www.urfu.ru

*Abstract:* Energy performance in household systems of power supply input depends on consumers of the electric power in many respects [1-6]. If the power consumption based on operation of household electroreceivers is consciously regulated by the ultimate consumer (the choice of analogs with a smaller rated power, peak capacitance decrease, operation of the electroreceiver reduction [9-10]), the electricity usage of lamps is not that obvious and its control should be paid a special attention and an additional research should be carried out. On the basis of measurements held in household the lamps energy indicators were got and analyzed. The comparison of different lamp types being applied in apartments today was made. Total daily working costs according to actual tariffing were calculated.

*Key-Words:* electroreceivers, energy efficiency, luminous intensity, logger, load curves, UPQI, lamps market.

## 1 Introduction

Since the first electrically powered lamps appeared (inventions of Jobard, Delarue and Goebel in 1838-1854), the lamps market underwent serious changes caused by aspiration to energy saving (Fig. 1). The major disadvantage the incandescent lamps had was a short operating term. Opening a halogen cycle was a serious step in development of lighting devices and in 1949 OSRAM made an application for halogen lamps patent. The compact fluorescent lamps, which present a type of gas-discharge lamps, appeared soon (in the beginning of the 80th) and assumed use of mercury vapors harmful for one's health. Therefore new lamps with light-emitting diodes, safe for the human, were launched onto the lamps market. Moreover, LED lamps consume less electric power without replacement during a long period of time [8].

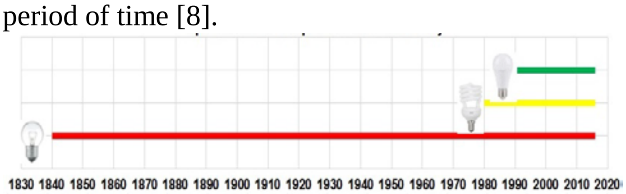


Fig. 1. Household lamps usage provisional scale.

Due to a large number of names of the lighting devices applied in household conditions, today an urgent task is both the quantitative and qualitative determination of its light flux performance, and also the analysis of its energy efficiency. Obtaining the characteristics and analysis of different types of lamps and their load curves and also comparison of lamps operating cost parameters will allow revealing reserves aimed to increase the energy efficiency and to develop programs for energy charge optimization.

## 2 Materials and methods

For finding solutions of mentioned objectives initial investigations in household electrical power supply systems (apartment) are executed. Measurement of Unified Power Quality Index (UPQI) and reading load curves were accomplished by means of the UPQI logger Chauvin Arnoux CA 8335+ (Fig. 2). On the basis of the data obtained load curves are made, analyzed and compared.

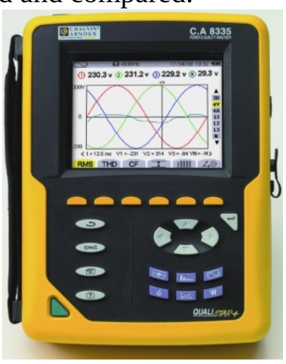


Fig. 2. The instrument used.

## 3 Lamps classification

Nowadays there are several types of energy saving lamps besides incandescent lamps:

| № | Type | Operating life |
|---|---|---|
| 1 | halogen, or upgraded incandescent lamps of A- and B-classes | 2—3 years |
| 2 | compact fluorescent | 6—20 years |
| 3 | LED | 3—4 years |

During the research operating characteristics of 15 lamps representing different lighting types have been measured overall (Table 1). Measurements with per-second discretization were taken within 24 hours of lighting elements continuous work in household network of 220 V.

## 4 Measurement and its analysis

### 4.1 Lamps energy indicators and energy consumption

By means of UPQI logger the averages of capacitance, current and electrical power factor per day for each of 15 lamps were obtained (Table 2). As for daily energy consumption, which is illustrated in Fig. 3, even the incandescent lamp with the smallest power rating among provided in this experiment consumes more kWh than fluorescent and LED lamps.

### 4.2 Lamps operating costs

According to the measured energy consumption and actual tariffing taking into account a two-tariff rate (in 2016 in Sverdlovsk region the rate for 1 kWh of the electric power makes 3.42 rub in the afternoon and 1.61 rub at night), daily working costs of lamps were calculated (Fig. 4).

### 4.3 Total harmonic distortion

The analysis of PQI based on the example of total harmonic distortion shows that distortion has the greatest values in case of fluorescent and LED lamps (in the first case it is in almost one range regardless of power rating), i.e. electroreceivers with non-linear volt ampere characteristic (Fig. 5). THDi value being no higher than 10% (incandescent lamps) is normal, and operation of the electroreceiver with such indicator doesn't cause failures in equipment operation. If THDi exceeds 50% (fluorescent and LED lamps), it means a high level of a network contamination by harmonicas (a high voltage and current distortion) and a possibility of failures (including an electroreceivers failure) [7]. Therefore application of a large number of such lamps in the household network with no compensating devices can badly affect quality of the network electric power.

## 5 Comparative analysis for lamps with an equal luminous intensity

For the experiment lamps of each type having approximately equal luminous intensity (650 Lm) have been chosen at the different nominal capacitances:

| № | Type | $P_{nom}$, W | $\Delta P$, W | $\Delta P_{\%}$, % |
|---|---|---|---|---|
| 1 | Incandescent lamp | 75 | 1,44 | 1,9 |
| 2 | Fluorescent lamp | 20 | 0,23 | 1,15 |
| 3 | LED lamp | 8 | 0,11 | 1,37 |

### 5.1 Loading spread

To consider the stability in operating of each lamp type and to estimate the most optimum alternative for usage the maximum daily loading spread has been marked out (Fig. 6). Within the conventional operating period, which is equal to 3 min. 20 s, the largest difference of capacitances in fluctuation ΔP is determined for each lamp and further the difference ΔP as a percentage w.r.t. lamp rated capacitance is calculated (Fig. 7).

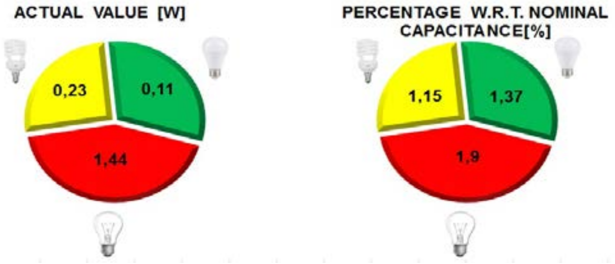


Fig. 7. Nonconforming load values.

### 5.2 Nonconforming load indicators

The load curves were made for all three lamps with equal luminous intensity being compared. In Fig. 8 the generalized loading curve with 1 s discretization is presented. The dotted line indicates mathematical expectation for the period under measurement, and, as comparison, the every second rms deviation on selection of 86400 values of the measured period is given (the curves are made according to the rms values of the measured parameter (power), and the expectations and deviations are calculated on this basis).

## 6 Conclusion

1. In case of the identical luminous flux the capacitances of the incandescent lamp, fluorescent

lamp and LED correspond as 100:27:11 respectively.
2. Nonconforming load fluctuations of the considered incandescent lamp, fluorescent lamp and LED make 1.9%, 1.15% and 1.37% of nominal capacitances respectively which proportionally affects stability of a luminous flux.
3. In case of the actual tariffing of 3.42 rub/kWh in the afternoon and 1.61 rub/kWh at night, electric power cost on terms of continuous operating for lamps with the identical declared luminous flux (650 Lm) makes 4.62, 1.14 and 0.46 rub/days respectively for the incandescent lamp, fluorescent lamp and LED.
4. The choice of lighting devices for the large territories, such as enterprises, deserves a special attention and shall be followed by additional measures for harmonicas compensation to prevent network from failures.

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# 7 Appendix

Table 1. List of lamps under investigation.

| Firm | Model | $P_{nom}$, W | Firm | Model | $P_{nom}$, W | Firm | Model | $P_{nom}$, W |
|---|---|---|---|---|---|---|---|---|
| Incandescent lamps | | | Fluorescent lamps | | | LED lamps | | |
| Kalashnikovo | T 150 | 150 | Navigator | NCL-4U-30 | 30 | Forza | A60-12 | 12 |
| Svet XXI veka | 230-95 | 95 | Forza | 25-4100 | 25 | Navigator | NLL-A60-10-2.7K | 10 |
| TDM Electric | B 230-75 | 75 | Kazhdy den | FST2-20-2.7K | 20 | Forza | A60-8 | 8 |
| Camelion | 60/D/FR | 60 | Volpe | CFL-H T2 | 15 | Navigator | NLL-G45-5-4.2K | 5 |
| Philips | 230-40 | 40 | Feron | ELC73 | 11 | IKEA | LED1012G5 | 3,5 |

Table 2. Energy indicators measured.

| Lamp type | Incandescent lamps | | | | | Fluorescent lamps | | | | | LED lamps | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pnom, W | 40 | 60 | 75 | 95 | 150 | 11 | 15 | 20 | 25 | 30 | 3,5 | 5 | 8 | 10 | 12 |
| Paver, W | 38,92 | 56,91 | 68,51 | 87,66 | 144,71 | 5,82 | 11,87 | 16,94 | 18,56 | 23,37 | 3,41 | 4,54 | 6,80 | 8,97 | 10,58 |
| Qaver, Var | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 8,02 | 16,55 | 21,94 | 26,51 | 34,81 | 4,96 | 6,81 | 11,86 | 13,50 | 18,12 |
| Saver, VA | 38,92 | 56,91 | 68,51 | 87,66 | 144,71 | 9,91 | 20,37 | 27,72 | 32,36 | 41,93 | 6,02 | 8,18 | 13,67 | 16,21 | 20,98 |
| Iaver, A | 0,172 | 0,256 | 0,312 | 0,399 | 0,649 | 0,04 | 0,092 | 0,126 | 0,146 | 0,189 | 0,027 | 0,037 | 0,060 | 0,074 | 0,094 |
| Cosaver | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 0,59 | 0,583 | 0,611 | 0,574 | 0,558 | 0,567 | 0,555 | 0,498 | 0,554 | 0,504 |

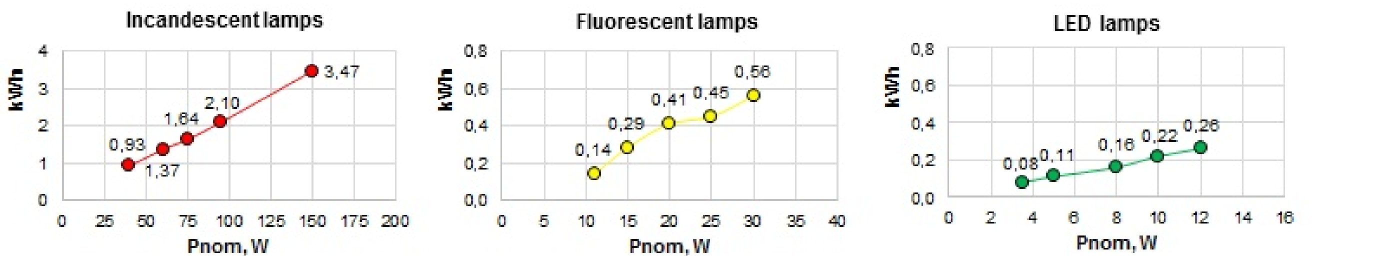


Fig. 3. The lamps power usage.

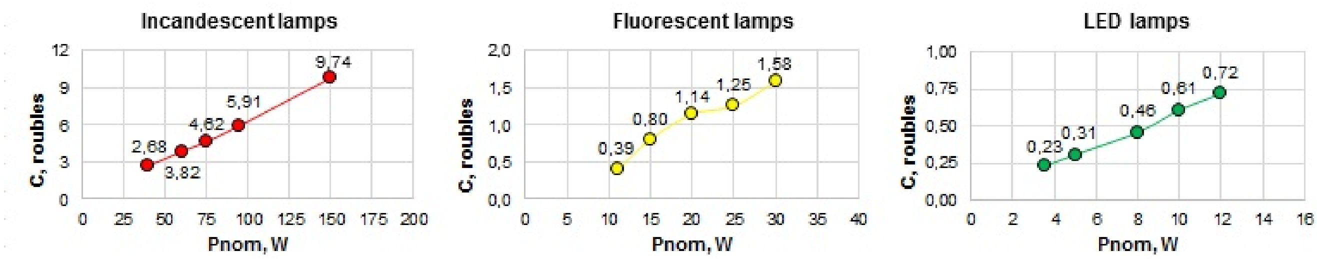


Fig. 4. Daily working costs.

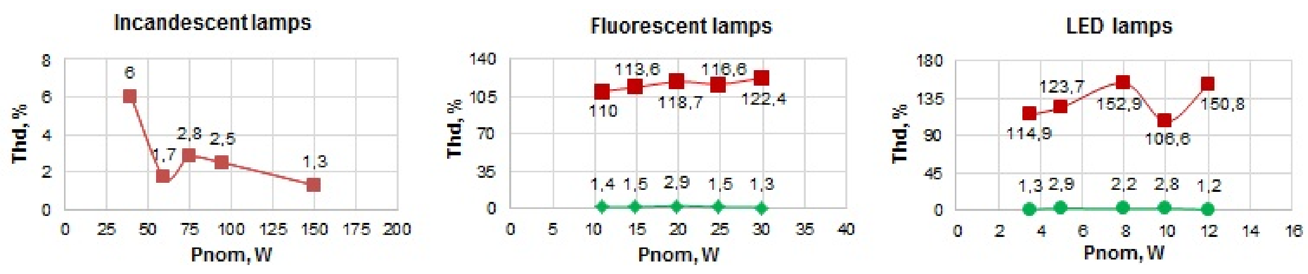


Fig. 5. Total harmonic distortion of the current (red) and voltage (green) in a day.

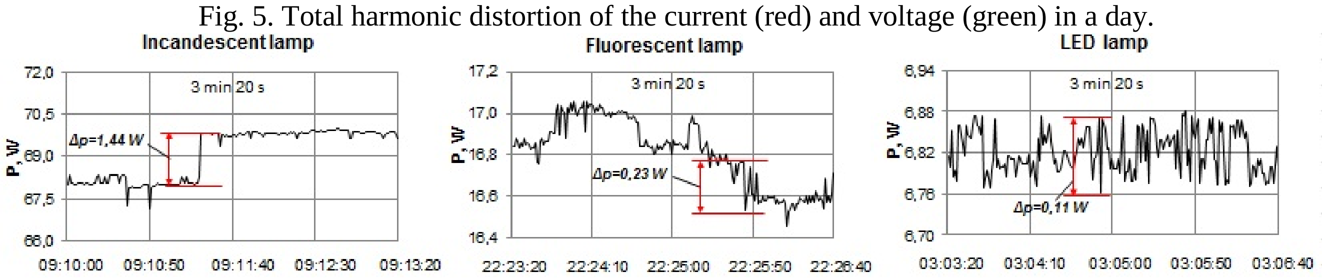


Fig. 6. Nonconforming load and its spread.

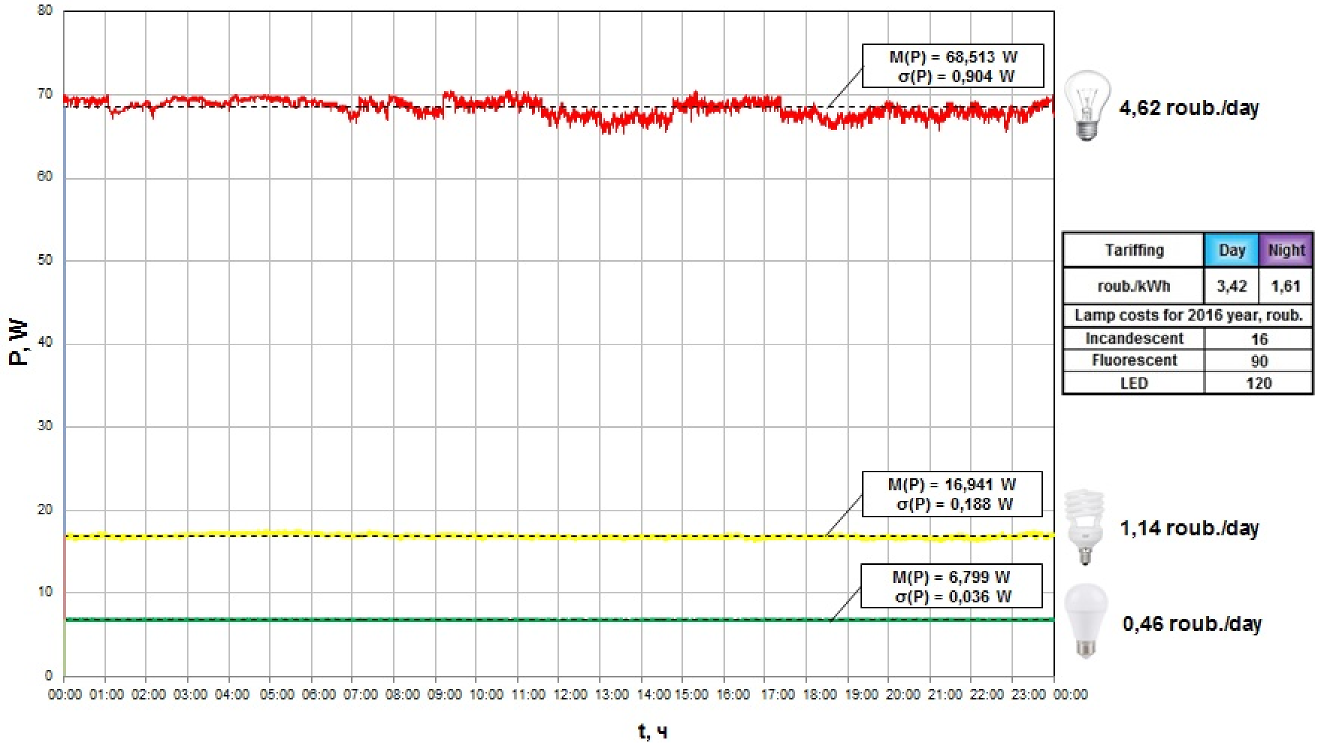


Fig. 8. Mathematical expectations and rms deviations daily.