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DESIGN OF SOLAR-POWERED LED ROAD LIGHTING SYSTEM

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ABSTRACT

Turkey is rich in terms of renewable energy sources and, therefore, is now encouraging the use of sustainable clean lighting systems in road applications. High pressure sodium lamp is the most widely used type in main roads, but other types of lamps such as mercury vapour lamps or metal halide lamps can be utilized for street lighting. Since it enables energy and money saving, LED light technology has replaced high pressure sodium lamps nowadays. Once solar power system (PV) is integrated with LED lamp for street lighting, the amount of saving and local impact might be enriched.

LEDs used as light sources in road lighting luminaires with rising lumen values, decreasing junction temperature, higher colour rendering efficiency, longer lifetime have become more efficient than many light sources with the latest developments. Since the structure of the luminaires in which the LED light sources are used differs from that of the conventional light sources, the optical, thermal and electrical design of the LED luminaires must be considered differently. Thus, this study concentrates upon design considerations and the operating principle of solar-powered LED road lighting luminaire in details. Also, a simple solar panel system was designed and the economical values obtained at the end of 20 years were compared when using the on-grid system and the off-grid system.

Keywords: solar-powered LED luminaire, road lighting, energy saving

1. INTRODUCTION

When evaluated in terms of usage areas of electric energy, it becomes clear that the consumption amount in parks, gardens and road lighting areas is high and it is vital to save on energy in these areas. Providing the same lighting level with less energy consumption without compromising the quality of lighting and using more efficient lighting luminaires as well as obtaining good lighting conditions is energy saving in lighting. The necessity to save energy in lighting caused a great deal of increase in the use of renewable energy. Because the sun is an efficient solution to generate renewable energy since its rays reaches everywhere on earth and free to harness, the renewable energy obtained from the sun has become one of the major energy sources in many applications [1]. Because of being convenient in panel selection depending on the needs, its use in off-grid environments and its integration into existing structures, the use of photovoltaic panels, which is a way of obtaining renewable energy, has become widespread in a short time in lighting systems [2]. Many studies in the field of LED lighting have validated that LED lighting systems are both economically feasible, energy saver as well as preventative of CO_2 emissions [3, 4–9].

Nowadays, thanks to advances in lighting technology, LED lighting systems which are used in many areas offer innovative and timeless solutions in park, garden and road lighting areas. The use of LED luminaires with longer lifetime, higher colour rendering efficiency, easier regulation of luminous flux and lower operating costs than tradi-

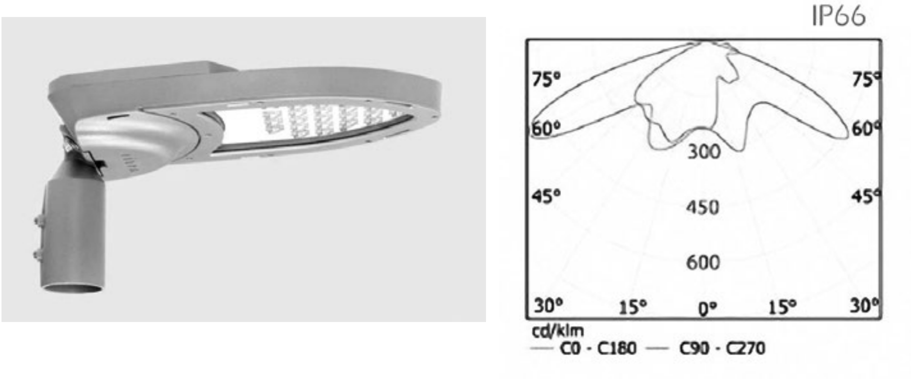


Fig. 1. LITPA LYS20/DC Solar-Powered LED Luminaire

tional luminaires has been an energy-efficient application in recent years. With the ever-evolving technology, the luminous efficiency factor (lm/W) values of the lumen-generated luminous flux per lamp power are increasingly rising and the use of LED light sources in road lighting applications is increasing day by day. [3]

Diodes consisting of semiconductor materials emit light when applied the current and current is obtained when it is exposed to light. When applied the voltage, the LED lamp starts to emit light when its electrons are activated. They are produced in such a way that they can give a wide spectrum of light ranging from infrared to violet [10,11].

Photovoltaic modules are the elements that convert solar energy into electricity. Photons from the sun transfer their energy to the junctions in the cells on a semiconductor module. This transmitted energy triggers the electron movement, which leads to electric current. This electrical current can be used directly as a direct current by connecting a load between the contacts of the cell. [2] The acquired electric current can be used as direct current (DC) or alternatively can be converted to alternating current (AC) or stored for later use [10].

In terms of the amount of solar energy radiation in Istanbul, especially in the winter months, is

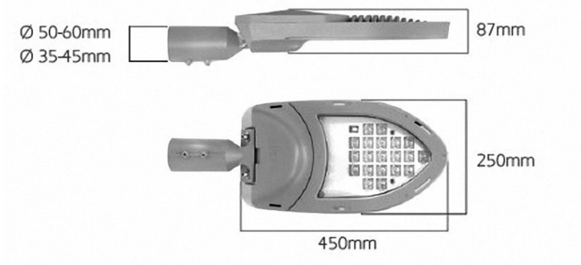


Fig.2. The Dimensions of LITPA LYS20/DC Solar-Powered LED Luminaire

very low levels of lighting energy should be provided at the lowest powers. For this reason, we produced a luminaire with low powers for this system.

2. DESCRIPTION OF SOLAR-POWERED LED ROAD LUMINAIRE DESIGN COMPONENTS

We have designed and produced solar-powered LED lighting luminaires for walking paths, parks and gardens. We can produce our luminaires 33W-45W-67W, and we did not need to produce high-powered luminaires as the system would work with solar energy. The luminaire we have developed is also suitable for use in the road categories M3 and M4. We have also prepared infrastructure for the streets in the M2 road category and we are in the design phase.

Among our targets, we are also planning to develop this type of luminaires for the roads in the M1 category. We plan a solar powered system with sensor and different dim levels that can program itself during the night. That is why our goal is to make sure that the batteries we use have longer lifetimes or are smaller in sizes. In the next stage, we plan to add both the solar and intelligent automation program to the luminaire. Furthermore, the motion sensor will reduce the dim level when not needed.

As the system's nature requires, we did not use the standard drivers sold on the market. In our solar electronic board, Figs. 1,2,3, we used current fixing module, diode, 2 pin terminal, 3 pin terminal, 6 pin connector cable, 6 pin SMD connector, 6 pin horizontal connector.

In order to provide energy efficient solutions for lighting walking roads, parks, gardens and roads, it is necessary to use LED light sources with high luminous efficiency factor values in LED street lu-

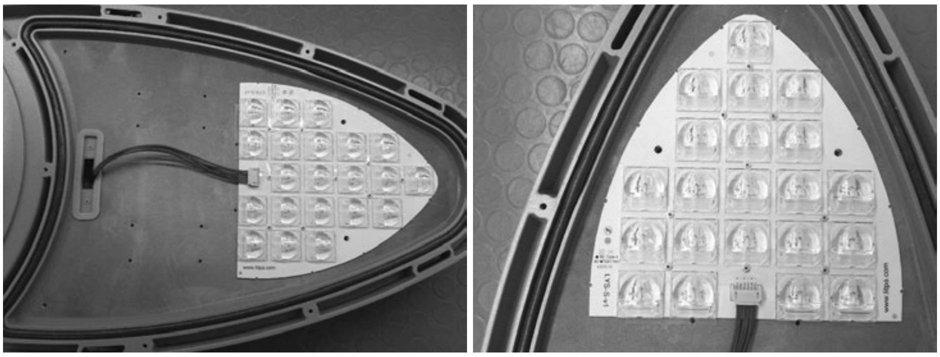


Fig.3. The PCB of LITPA LYS20/DC Solar-Powered LED Luminaire

minaire design. Power LED chips with highly efficient Bin codes in Lumileds, Nichia and Samsung brand 3535 packages are preferred. The luminous efficiency of the luminaire is 130 lm/w and above. Since there is no AC / DC conversion and we have no driver losses, we aim for 160 lm/w. Thanks to the flexibility in the luminaire design, the luminous flux obtained from the luminaire (luminaire size: 450mm×250mm) is obtained as 8.000 lm depending on the requirements of the environment lx level.

It is aimed to provide effective thermal dispersion and cooling by using aluminum PCB in luminaires. The thermal conductivity will be preferred to a minimum of 1.1 W/(m·K). A PCB will have 21 LED chips. Cable connections on PCBs will be via the connectors on them.

We used asymmetric street lighting lenses with minimum shade and minimum glare values to optimally illuminate roads and streets. In fixed angle poles and consoles, the angle of light cannot be regulated. We, however, designed the angle in such a way that it can be regulated form a junction piece on the luminaire.

When selecting the luminaire body, the cooling channels on the body will ensure that the life of the LED chip and its efficiency are at the highest level. The body is manufactured by aluminium injection method and it is resistant to corrosion and rust because it is aluminium. In addition, this aluminium body is painted with polyester, electrostatic powder paint, so, it is very long lasting and rusting free. Moreover, it is not exposed to corrosion in the outside environment. Silicone sealed gasket is used between the back cover and the body. Silicone-based sealing gaskets are used between the windshield and the body. Connection screws are to be stainless steel. Glass will be tempered and roved.

The luminaires are produced with IP66 protection class compatible with outdoor applications.

Instead of the driver in the solar-powered LED lighting luminaire, we designed a special DC / DC card that can work with both 12 V systems and 24V systems.

Chemical materials in the solar-powered LED lighting luminaire, silicon lens structure on the LED, adhesives used to stick the lens and PCB together, thermal band or thermal paste used to provide thermal conduction between PCB and body, body IP materials such as gaskets contain chemical volatile organic compounds (VOCs). In the event of using chemical volatile organic compounds on or near the LED, which are not compatible with it, the lighting system is damaged and the lifetime of the LED used and accordingly the lifetime of the luminaire is reduced.

3. DESIGN OF SOLAR-POWERED LED ROAD LIGHTING LUMINAIRE

In this section, the design of solar-powered LED lighting luminaire system is describing. Luminaire design, prototype production, electronic card design, mechanical design and system performance tests are the steps of the development of solar-powered LED lighting luminaire.

3.1. Luminaire Design

In the project, firstly, research studies were conducted by our engineering and design department about LED lighting technologies and LED products. These studies have been deeply and systematically prepared and database has been created. The luminaire design has been made based on these data. As a result of this study, guidelines about different applications and products in the world and in the literature have been obtained and the general specifications of the luminaires have been determined.

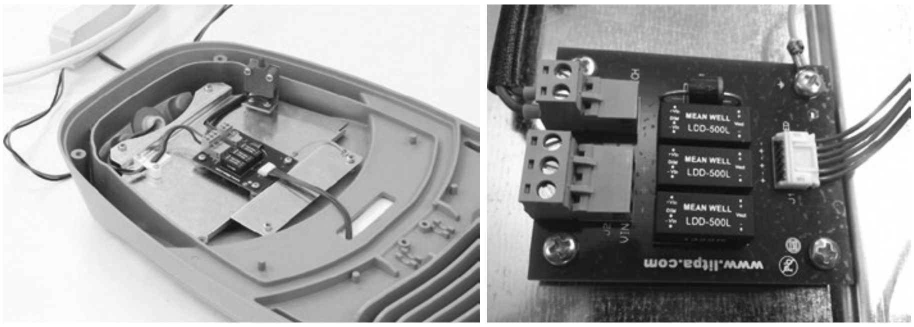


Fig. 4. The Electronic Card of LITPA LYS20/DC Solar-Powered LED Luminaire

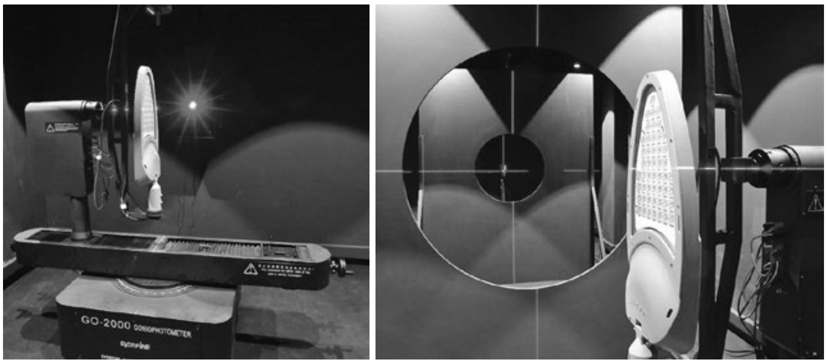


Fig. 5. The Measurement of LITPA LYS20/DC Solar-Powered LED Luminaire

Research and development activities carried out in the luminaire design include the design of a street lighting luminaire consisting of LEDs, the prototype production and the verification of its performance, and the determination of the system's overall energy consumption and lighting performance. The choice of LED, the number and configuration of the LEDs on the luminaires (distance and angles between them) will be determined in line with optical and thermal parameters. The detailed design of the optimum luminaire will be done in computer environment considering the manufacturability, aesthetic, ergonomic and mechanical aspects. Optical and thermal simulations are performed and the design has been verified in the computer environment before the detailed design and technical drawing work have started. This phase has been essential in the production of the optical and thermal design of the product.

3.2. Prototype Production

In this research and development stage, the manufacturing drawings of the components that make up the luminaire will be obtained in the 3D design environment on the computer. In design, a 3D-CAD design package is used and each part and moulds are simulated in computer environment. Luminaires made with detailed designs are transferred to prototype production and after prototype parts have been verified, mould designs have been made for each part individually. It has been carried out within the possibilities of operating moulds or supplier companies.

3.3. Electronic Card Design

The PCB, Fig.4, as the light source of the luminaire consists of 7 series, 3 parallel circuits, and has 21 LEDs. Each parallel circuit is driven by its own current stabilizer. The current-stabilizing module has been selected according to the current we want to drive the LEDs. We selected current stabilizer of 350mA for 22W, 500mA for 33W and 700mA for 48W. We also placed a diode on the circuit that provides reverse polarity protection to prevent the risk of reversing the – and + inputs coming from the battery. Our current-stabilizing modules are to be fed by 24V DC battery voltage so that we can provide energy to 7 series of LEDs via the battery voltage obtained at the output.

The biggest advantage of this electronic card we have developed is that the controller on the system can supply the energy from the battery directly to the lighting luminaire. Thus, the need to use a classic driver in the luminaire is gone. AC / DC

Table1. Calculated Values for Photovoltaic Panel

Month	Energy/Day, kWh/m^2	Coefficient of panel tilt angle	Panel Efficiency,%	Panel Area, m^2	Daily produced amount of energy
1	2	1.15	0.167	1.64	0.629924
2	2.57	1.15	0.167	1.64	0.809452
3	4.2	1.15	0.167	1.64	1.32284
4	5.28	1.15	0.167	1.64	1.662999
5	6.3	1.15	0.167	1.64	1.984261
6	6.79	1.15	0.167	1.64	2.138592
7	6.79	1.15	0.167	1.64	2.138592
8	6.07	1.15	0.167	1.64	1.911819
9	5.09	1.15	0.167	1.64	1.603157
10	3.74	1.15	0.167	1.64	1.177958
11	2.37	1.15	0.167	1.64	0.74646
12	1.8	1.15	0.167	1.64	0.566932

converter is not necessary and the system works much more efficiently from DC to DC.

The electronic board is made of aluminium material with a thickness of 1.6 mm and a heat transfer coefficient of 1.1 W/(m·K). The cable connections were made via the connectors on the PCB. The LEDs and connectors on the card will be automatically sequenced and quality controlled.

3.4. Mechanical Design

The entire luminaire will be designed depending on the optical and thermal priorities. Mounting brackets can be configured so that they can be mounted on both poles and consoles and can be angled up to 15 degrees in 5 degrees increments in + and – directions. The weight optimization was made so as not to affect the thermal performance adversely. It is user-friendly as it is easy to mount and install. Moreover, its ergonomics design makes subsequent service and maintenance activities easy. In this sense, the electrical connections and electronic card maintenance services can be done by opening the back cover without touching the LED part.

3.5. System Performance Tests

Following the prototype production, the product type and performance tests were first made in the goniophotometer system in Litpa Lighting laboratories, Fig. 5, and the second stage tests were carried out in line with the CE marking requirements in the independent testing laboratories. The quality of the product for the industry, such as resistance to environmental conditions and cost of use (energy consumption, ease of maintenance, spare parts, etc.) are extremely important for customer satisfaction and tests under the relevant standards have been thoroughly applied. Energy consumption and lighting performance of the complete system will also be tested and necessary improvements will be made.

4. DESIGN OF SOLAR LED LIGHTING SYSTEM

Traditional grid-powered lighting systems are a lot less complicated than PV lighting systems when their design and installation requirements are considered. PV lighting systems also have higher initial purchase and maintenance cost for many of their components when compared to grid powered traditional lighting systems. Therefore, there is relatively limited usage of lighting applications appropriate for PV lighting systems. Nevertheless, it is possible to develop successful PV lighting applications with the help of comprehensively planned design processes. [12]

The proposed photovoltaic system, which consists of a solar panel, the LED road lighting lu-

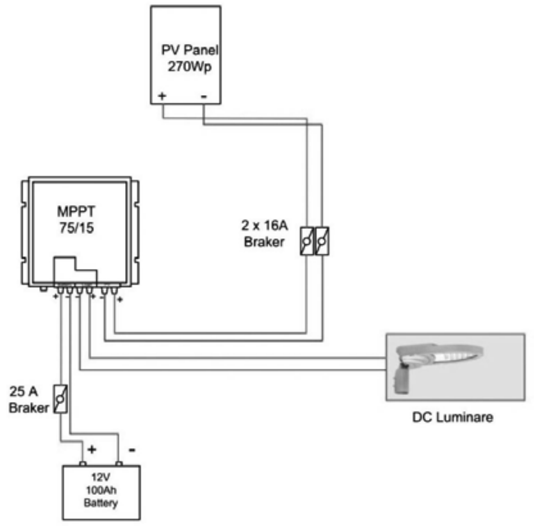


Fig. 6. The Block-Diagram of the Lighting System

minaire, a charge controller/MPPT, an electrical energy storage battery, are illustrated in Fig.6. The working principle of this system (the photovoltaic principle) can be described as the next:

– The solar panels receive solar radiation throughout the day;

– After that, the solar radiation is converted into electrical energy through charge and discharge controller;

– Finally, that electrical energy is stored in the rechargeable battery.

The storage place of the electric power generated by the solar PV panel is the rechargeable battery during the daytime. When the battery is fully charged, the battery charging unit detects this and stops charging and keeps system ready for use. At night, the solar energy stored in the rechargeable battery is released to power the LED lighting system and light the street lamps. The street lights function steadily as the design of the batteries can meet the voltage and current requirements.

5. EXPERIMENTAL RESULTS

Experiment was conducted in Istanbul. There are many parameters that affect the efficient operation of the photovoltaic system. Experiment results are summarized at the Table 1. This table indicates the required parameters' values in order to calculate the amount of energy daily produced.

The determination of the amount of energy to be consumed daily is a crucial part in designing off-grid PV system. We have determined the photovoltaic power according to the daily energy consumption demanded by the user.

Table 2. Solar Cell Parameters (Tommatech), [15]

STK Electrical Parameters	
Nominal Power (Pmax)	TT275–60P
Open Circuit Voltage (V_{OC})	37,30 V
Short Current Voltage (I_{SC})	9,20 A
Nominal Power Voltage (V_{mp})	31,3 V
Nominal Power Current (I_{mp})	8,78 A
Number of Cells	60 (156*156)
Dimension (mm)	1640*990*35
Weight (kg)	19
Max. System Voltage	1000W DC
Max. Series Fuse Rating	15A
Operation Temperature	-40 ^{0}C to +85 ^{0}C

In the first two columns of the Table 1, the daily amount of energy we obtained and the coefficient of panel tilt angle are given. The daily amount of energy values in [kWh/m^2] are based on data from Fig. 7, [13].

The coefficient of tilt angle of the panel for Istanbul is considered as 1,15. The coefficient of panel tilt angle has been calculated in December for the northern latitude of 40 ° 11 ' in which Istanbul is located.

According to panel catalogue information given in Table 2, panel efficiency is calculated by considering the electrical parameters of TT275–60W panel for 1000 W/m^2. When the radiation is 1000 W/m^2 and the rated power is 275 W/m^2, the efficiency of a panel of 1640 mm × 990 mm × 35 mm is acquired as 16 %.

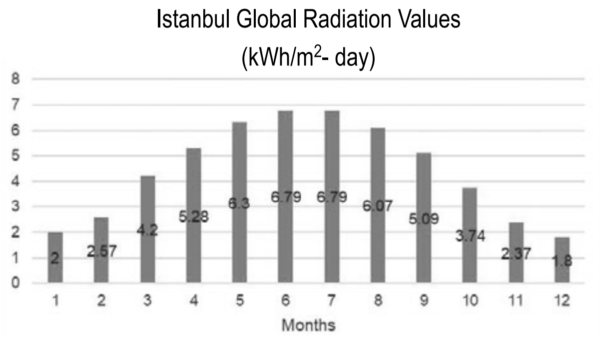


Fig. 7. Istanbul Global Radiation Values (kWh/m^2) per day

The amount of energy daily produced is calculated by multiplying these four parameter values: energy/day in kWh/m^2, coefficient of panel tilt angle, panel efficiency and panel area in m^2.

The panel that produces in December energy per day equal to 0.56 kWh meets the energy we need as 0,42 kWh. Therefore, TT275–60W panel type is suitable for this system.

$$Ppv = \frac{E(L)}{\eta(s).PSH} Sf,$$

$$Ppv = \frac{48W \ x9 \ hrs}{0,9 \ .2,1 \ hrs} x1,2,$$

$$Ppv = 274,28W,$$

were *Sf* is the safety factor, *Ppv* is the panel power, *E(L)* is the daily energy consumption, *η(s)* is the system efficiency, *PSH* is the peak Sun hours

$$Cwh = \frac{E(L)x\,a(t)}{DOD\,x\,\eta(c)\,x\,Vb},$$

$$Cwh = \frac{(48x9)x1}{0,5x0,95x12},$$

$$Cwh = 75.79 \text{ A·h},$$

where *a(t)* is the number of autonomous days, *n(c)* is the efficiency of battery, *Vb* is the voltage of battery, *Cwh* is the battery energy storage.

5.1. Charge Controller/ MPPT

$$\text{V(in)} = \text{V(oc) of the PV Panels} = 37,3 \text{ V}.$$

$$\text{I(in)} = \text{I(sc) of the PV Panels} = 9,20 \text{ A}.$$

$$\text{V(out)} =$$
$$= \text{Charge Voltage of the battery group} =$$
$$= 12 \text{ V} - 14,4 \text{ V}.$$

$$\text{I(out)} = \frac{\text{Pp x } \eta(\text{charger})}{\text{Charge Voltage}},$$

$$\text{I(out)} = \frac{275 \times 0,95}{14,4 \text{ V}},$$

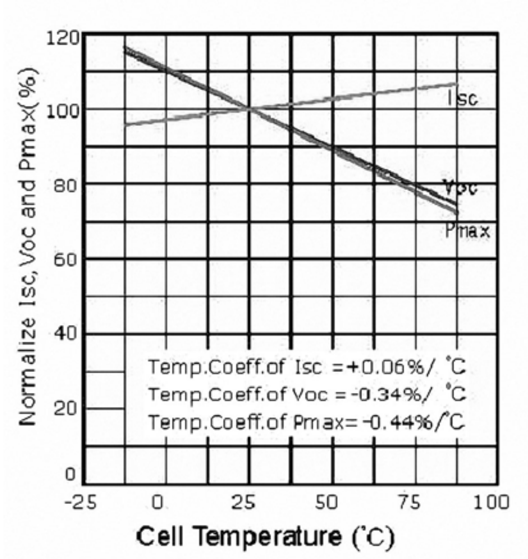


Fig. 8. Temperature dependence of *Isc*, *Voc* and *Pmax*, [15]

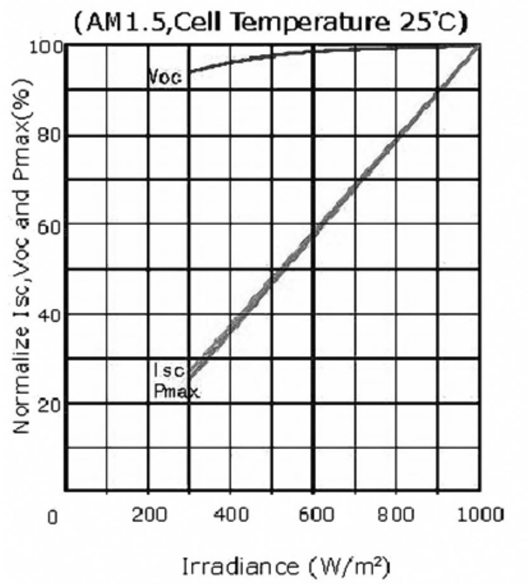


Fig. 9. Irradiance dependence on *Isc*, *Voc* and *Pmax,* [15]

$$\text{I(out)} = 18,14 \text{ A},$$ [16].

While the solar panel in the blog diagram of the lighting system shown in Fig. 8 is calculated, safety factor 1.2; daily energy consumption 9 hours, lamp power 48 W, system efficiency 0.9 and peak sun hour 2.1 were taken. Accordingly, a panel power of 274.38 W/m^2 was obtained. When calculating the battery capacity, the autonomic duration is 1 day, the battery efficiency is 0.95, the battery voltage is 12V and the DOD (Depth of Discharge) value is 0.5 were taken. Accordingly, the battery capacity is calculated as 75.79 A·h. *Voc* = 37.3 V, *Isc* =

Table 3. Installation Cost of Unit Street Lighting System (Solar-Powered LED)

LYS20-DC ROAD LIGHTING SYSTEM						
No	**Components**	**Model**	**Quantity**	**Unit**	**Price**	**Total Price**
1	Solar Panel	270	1	pcs	$87	$87
2	Road Lighting Luminaire	48W	1	pcs	$113.5	$113.5
3	Battery Gel 12V	100Ah	1	pcs	$140	$140
4	Solar Charger	MPPT 75/15	1	pcs	$90	$90
5	Timer		1	pcs	$30	$30
6	Lighting Pole	4m	1	pcs	$200	$200
8	Cu Cable 4*2.5mm^2		50	meter	$1	$50
9	Montage cost		1		$400	$400
10	Electric Panel		1	pcs	$100	$100
						$1210. 5

Table 4. Installation Cost of Unit Street Lighting System (Grid-power LED)

LYS20-AC ROAD LIGHTING SYSTEM						
No	**Components**	**Model**	**Quantity**	**Unit**	**Price**	**Total Price**
1	Road Lighting Luminaire	52W	1	pcs	$108	$108
2	Lighting Pole	4m	1	pcs	$165	$165
3	Cu Cable 4*6mm^2		50	meter	$1	$50
4	Montage cost		1		$400	$400
5	Electric Panel		1	pcs	$100	$100
						$823

9.2 A, the current was selected as MPPT 75/15 according to 18.14A.

6. LUMINANCE CALCULATION

Because of the fact that visual performance and visual comfort the users of road lighting are affected by road luminance and illumination measurement parameters, road-lighting installation requirements have to be shaped according to these fundamental aspects. [14] Street lighting systems must be designed tailor made for respective roads & streets and should provide adaquate level of illumination and illumination uniformity in relation to international street lighting standards such as EN13201.

The present paper studied quality parameters of the solar-powered roadway lighting using LED luminaires (48 W) for 300 m highway section with 2 lanes. The roadway lighting luminaires are placed on both sides of the road with the pole distance 8 m. In the case study, DIALUX software simulation was used in order to make a comparison between calculated illumination values and the illumination values of standard EN13201.

Figs.10, 11 presents the calculated illuminance and luminance distributions of the road. It should be noted that the all calculated values meet the requirements of EN13201 international standard for a road of ME4a class.

7. ECONOMIC ANALYSIS OF LED AND SOLAR-POWERED LED

The present paper studied the economic feasibility of the solar powered street lighting using LED luminaires (48 W) for 300 m highway with 2 lanes. Economic comparison for two kinds of street lighting design, namely, LED using grid power and so-

Table 5. Installation & Maintenance Costs of Street Lighting System Unit for 20 Years (Solar-Powered LED)

LYS20-DC ROAD LIGHTING SYSTEM FOR 20 YEARS						
No	**Components**	**Model**	**Quantity**	**Unit**	**Price**	**Total Price**
1	Solar Panel	270	1	pcs	$87	$87
2	Road Lighting Luminaire(5 years warranty/50.000 h lifetime)	48W	2	pcs	$113.5	$227
3	Battery Jel 12V	100Ah	2	pcs	$140	$280
4	Solar Charger (5 years warranty)	MPPT 75/15	2	pcs	$90	$180
7	Timer		2	pcs	$20	$40
8	Lighting Pole	4m	1	pcs	$200	$200
10	Cu Cable 4*6mm^2		50	meter	$1	$50
11	Montage cost		1		$400	$400
12	Electric Panel		1	pcs	$100	$100
						$1564

Table 6. Installation & Maintenance Costs of Street Lighting System Unit for 20 years (Grid-Powered LED)

LYS20-AC ROAD LIGHTING SYSTEM FOR 20 YEARS						
No	**Components**	**Model**	**Quantity**	**Unit**	**Price**	**Total Price**
1	Road Lighting Luminaire	52W	2	pcs	$108	$216
2	Lighting Pole	4m	1	pcs	$300	$300
3	Cu Cable 4*6mm^2		50	meter	$3.9	$195
4	Montage cost		1		$400	$400
5	Electric Panel		1	pcs	$100	$100
						$1211

lar power, is carried out. Each unit of solar powered LED street lighting system includes a 270 PV modules, a 100 Ah-12 V batteries, and a 48 W LED lighting luminaire.

Tables 3 & 4 show that the installation costs are 823 USD for LED lighting powered by grid and 1210.50 thousand USD for solar-powered.

Tables 5 & 6 show that the sum of installation, maintenance and operation costs of the system after 20 years for a single luminaire pole. In our project, 38 poles were used with a distance of 8 m on the 300 m ME4a type road. Accordingly, the unit cost of the system used in the system powered by solar energy is 1564 USD, and the cost for 38 poles is 59432 USD. The unit cost of the lighting system supplied by the network is 2558.84 USD, and for the 38 poles it is 97235.92 USD. By spending the same amount of power at the same light level, at the end of 20 years 97235.92 USD –59432USD = 37803.92USD was saved.

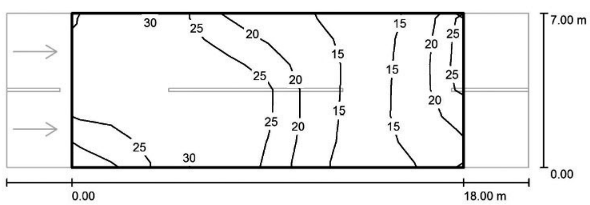
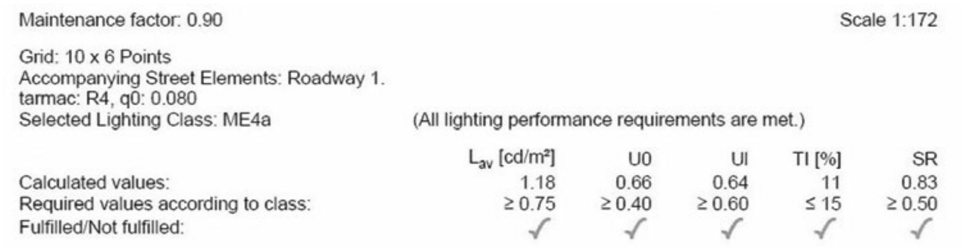


Fig. 10. Illuminance Calculation

Table 7. Cost Analysis of Both AC and DC Road Lighting System 12h /day in 20 years

LYS20-AC ROAD LIGHTING SYSTEM						
System cost ($)	**Total Power Consumption (W)**	**Lighting hours 12hrs×30daysx12months×20y**	**Electricity price ($) 1kWh**	**Total Energy Consumption (kWh)**	**Total Energy Cost ($)**	**Total System Cost for 20 years**
$1.211,00	52	86400	$0.3	4492.8	$1347.84	$2558.84
LYS20-DC ROAD LIGHTING SYSTEM						
System cost ($)	**Total Power Consumption (W)**	**Lighting hours 12h x 30days x 12months x 20y**	**Electricity price ($) 1kWh**	**Total Energy Consumption (Wh)**	**Total Energy Cost ($)**	**Total System Cost for 20 years**
$1.564,00	48	86400	-	4147.2	-	$1564


Maintenance factor: 0.90 Scale 1:172

Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R4, q0: 0.080
Selected Lighting Class: ME4a (All lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.18	0.66	0.64	11	0.83
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✓	✓	✓

Fig.11. Calculated Values

7. CONCLUSIONS AND REMARKS

Within the study the operating principles and design considerations for the proposed PV LED road lighting luminaire were described and analyzed in detail. Luminance calculation results of the laboratory prototype were analysed to verify the feasibility of the proposed method

Owing to the fact that they have many advantages over other technologies, solar powered LED street lighting systems have been made available in any many roads and streets. The luminaires used in LED technologies can easily be integrated into photovoltaic illumination systems.

The technology in LEDs has considerably improved in the past couple of years and are good alternatives to the conventional illumination systems. Simple drives, when control and dimming systems are considered, increased lifetime and luminous efficiency are some of the main advantages of using LEDs.

Moreover, luminosity flow can be controlled more effectively via LED luminaries, which allows us to save on an important amount of energy and diminish the public illumination expenditures.

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