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An Energy Efficient Lighting for Autonomous and Hybrid Nanogrid

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Abstract

The paper presents newly proposed and realized solution for autonomous and hybrid nanogrid lighting with energy efficient LED and low voltage DC supply. Experimental study of the LED lighting parameters in discharge mode of the batteries is made.

Index Terms: PV systems, DC grid for LED lighting, efficient and its aspects in discharge mode

1 Introduction

The increasing share of renewable generation gives many challenges for the development of the electrical installation projects. While the majority of the renewable structures can operate as grid connected, there are infrastructure situations in which the public grid connection is not applicable and autonomous operation is the only feasible solution (for example for mountain huts and other distinct buildings).

Traditionally the dominating type of loads in the buildings is AC and the majority of loads which are of DC type are supplied via AC/DC converters with efficiency typically ranging between 50-90%. In the case of autonomous PV systems the generated power is stored in batteries and afterwards converted and delivered as an AC. Since the majority of the loads are DC and the double conversion – DC/AC and after that AC/DC leads to significant losses it seems to be much more reasonable to implement hybrid AC and DC grid with direct DC use [1-8].

The international experience in the use of hybrid grids with PV systems for domestic applications shows promising practices and significant benefits [1-3]. It is considered that the use of DC Power from local PV units for supplying LED lighting and digital devices could improve the efficiency by nearly one third due to the decrease of power loss from conversion, Fig 1 [4,5].

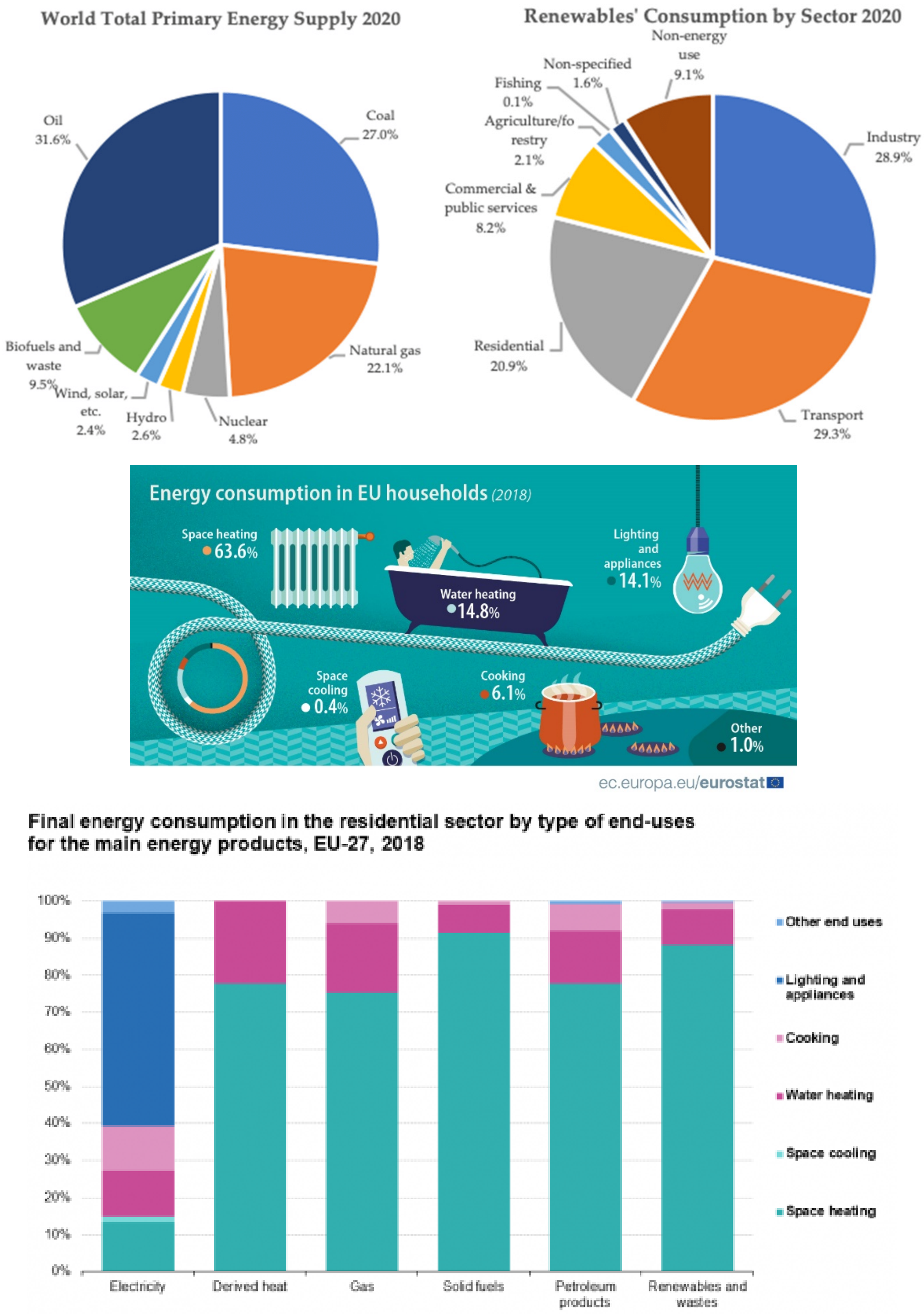

Fig. 1. Energy consumption [4,5]

2 Nanogrid Concepts, Structure and Lighting Solutions

2.1 Nanogrid concept

The main nanogrid concept used relies on the following principles [1]:

- prosumer centric behaviour;
- environment friendly and nature oriented action;
- increased DC / decreased AC power share;
- extended use of flexible load as cost efficient storage;
- reduced dependence from fossil generation sources.

2.2 System configuration [1]

The nanogrid configuration consists of the following elements (Fig. 2):

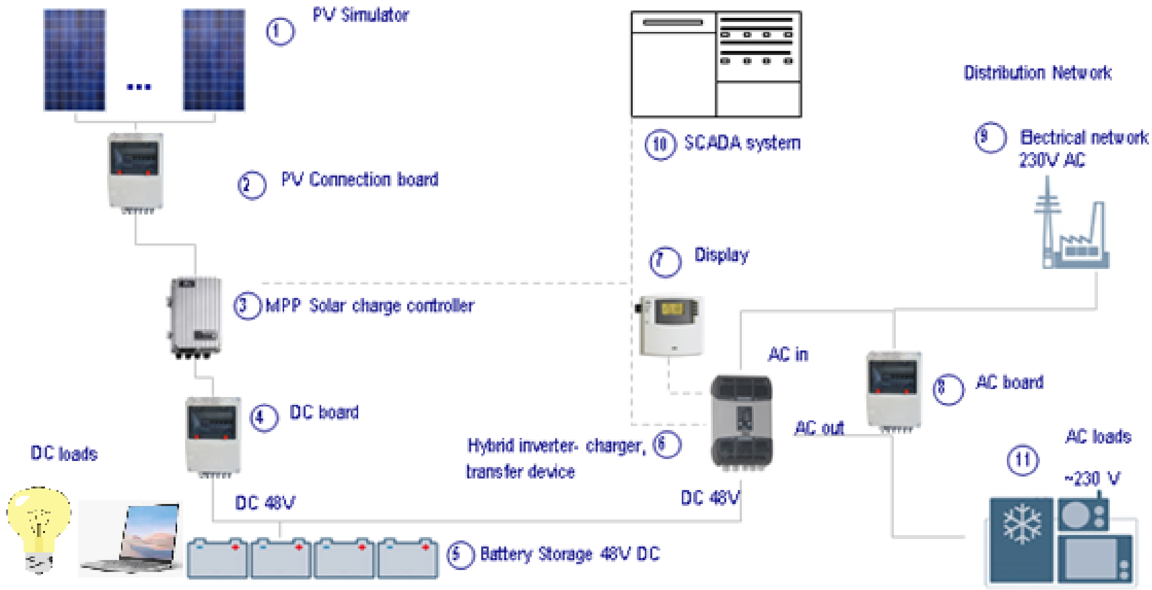

Fig. 2. System configuration

1. Photovoltaic (PV) generator.

2. PV connection board with overcurrent and over voltage protection.

3. MPP Solar charge controller with galvanic isolation.

4. DC board 48 V connecting the batteries, charging controller and hybrid inverter.

5. Battery storage: Lead acid VRLA battery.

6. Hybrid converter operating as bidirectional inverter, charger and transfer device with fully controllable parameters.

7. Display for visualizing and logging the basic parameters of the system.

8. AC board

9. Information system (SCADA) for measuring, monitoring and control.

10. Electrical loads - DC (LED lighting) and AC loads

2.3 Power demand for lighting and system battery capacity

The power demand for lighting in the near past was considerable. For the autonomous systems this led to high fuel consumption of the used diesel generator and significant manpower drain for its delivery. Traditionally the lighting installation was realized with different types of interior luminaires, predominantly with E27 socket.

Assuming constant power discharge and taking into account the lighting load power the battery parameters and discharge characteristics and components conversion efficiency, several lighting options with their technical performance are evaluated. The results are presented on Fig.4.

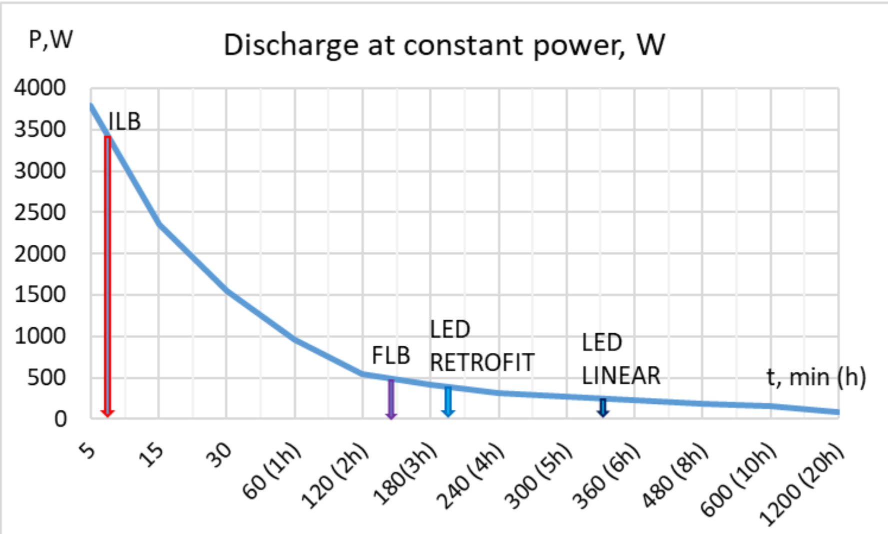

Fig. 4. Discharge characteristics with different types of lighting load (AC or DC grid)

The figure can assist the user for appropriate choice of different light sources (such as incandescent light bulb (ILB), fluorescent light bulb (FLB), LED Bulb (LED Retrofit) and LED Line (LED linear with taking into account the power demand and the maximum operation time for a typical battery cycle. As can be observed on Fig. 4, the longest discharge time, points to the use of LED luminaires with high efficiency strip lines [10] supplied directly by a DC grid.

Moreover, the efficiency of the LEDs rises with the decrease of their current/voltage. Thus, when the DC grid is directly fed by the battery voltage the LED voltage will start to decrease during the battery discharge process. This phenomenon allows longer operation period during the battery discharge cycle. An experimental study is performed to study this effect.

3 Experimental Study of the LED Lighting Parameters Supplied by Battery Fed DC Grid

The relationships between the electrical and lighting characteristics of the LED lighting sources, supplied by the DC grid were experimentally studied at TU-Sofia in conditions of simulated battery charge and discharge. For measuring of the lighting characteristics (radiated spectrum, luminous flux, color coordinates and CCT) calibrated radiometer with spectral range 200-1100nm and integrating cube [11] is used. The electrical characteristics of the LEDs were measured by calibrated multimeters and voltage source. The experimental setup is shown on fig. 5.

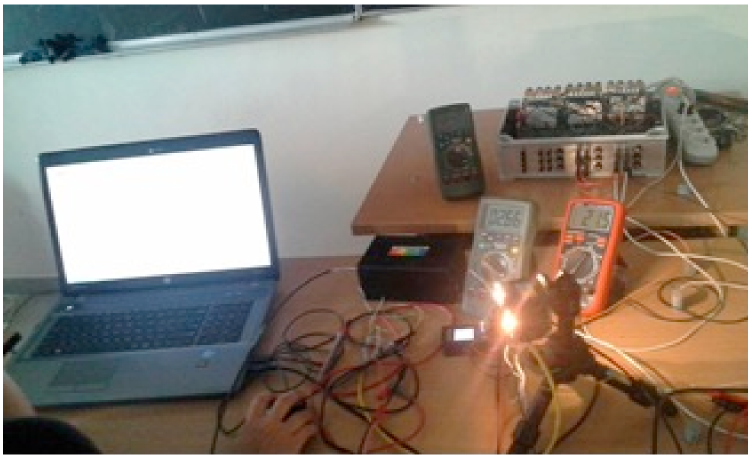

Fig. 5. Experimental setup

The change of single LED voltage (USLED, V), module-LED current (ISLED-MOD), single LED luminous flux (ΦSLED, lm), single LED radiance (W/m2.nm) and the corresponding CCT (CCT, K) were measured for different supplying voltages of the used LED modules (UMOD, V). For the different UMOD were calculated the power of the single LED and of the LED module (PSLED and PMOD, W) and the corresponding luminous efficacies (χSLED and χMOD, lm/W). The results in per unit are shown on Fig. 6.

The range of the voltages is based on registered values at battery charge in sunny days (maximum value 56 V) and the lowest battery voltage limit which allows switching to alternative power source (in this case – gasoline/diesel generator) and recharging the battery.

The declared CCT of the manufacturer is 3000 K and the measured at nominal voltage 48 V is 2940 K. The measured values are in the range of 2679 K (34V) – 2941 K (45-47V, 51-52V). The CCT practically remains stable for the expected working voltage range.

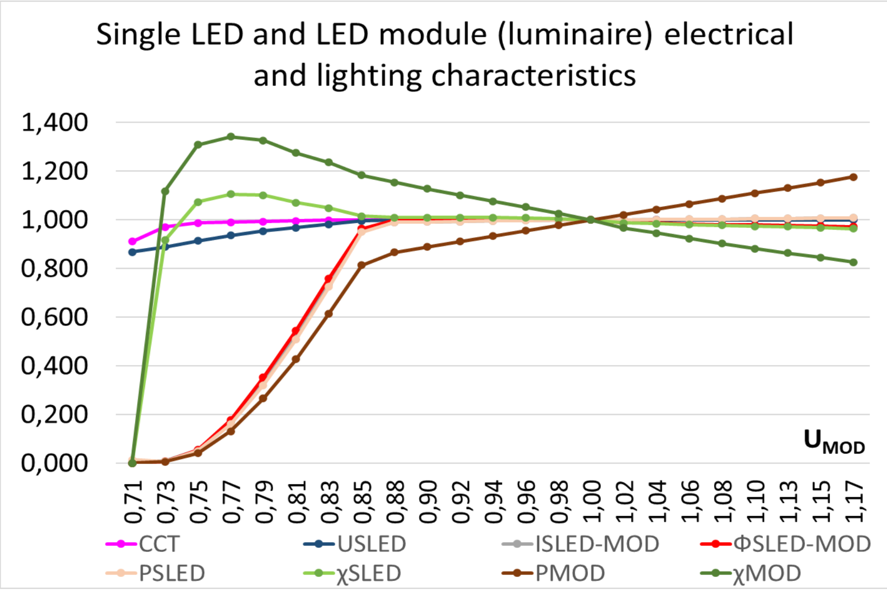

Fig. 6. Single LED and LED module (luminaire) characteristics with variance of the DC grid supplying voltages

It can be noticed that at 81% of the rated voltage (39 V), the CCT changes with less than 0.5% (2926 K), the luminous flux is 55% of the nominal, the needed power P, W is with 57% less than the nominal at 48V and the luminous efficacy is with 28% higher.

Based on the experimental results and the simulation data, presented on Fig. 4 and 6 a reconstruction of the lighting system using linear LED luminaires fed by battery voltage appears to be the most efficient and suitable solution.

4 Analysis of the Results

The solution of an advanced scheme and configuration of autonomous nanogrid with renewable energy sources for DC electrical supply of LED lighting gives an opportunity for prolonging the possible lighting duration as well as the battery discharge time with approximately 30%. The lower operation voltages during the discharge cycle of the battery also lead to extension of the expected life time of the LED lighting sources. This self-regulating approach is applicable for all kind of domestic applications and could be used not only in autonomous systems but also in hybrid grid connected systems. As can be observed from Fig.4 the LED line solution can provide 2 extra hours of operation compared to conventional LED bulb. Prolonging of the discharge time of the batteries brings many benefits especially during the winter season.

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