One energy-efficient solution in lighting and the basis for its implementation

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***Abstract*—Sources of energy based on fossil fuels are limited. Sustainable energy sources are underutilized. Switching to energy sources that are inexhaustible, and whose exploitation is available to all, reduces operating costs and reduces environmental pollution. The potential of solar energy in Serbia is 14%, but it is mostly unexploited. Percentage of energy from renewable energy sources in total energy consumption in Serbia is 21.2%. Solar energy accounts for only 0.03% of the total world energy production.**

The paper is divided into several parts. The first part is devoted to analysis of the applicable regulations and standards related to energy efficiency in Serbia, European and worldwide. The second part of the paper briefly presents the solar energy potentials of Serbia. The main part of this paper deals with specific practical problem of power street lights and gives the solution for energy efficient lighting. The initial steps of the preparatory activities for the implementation of the proposed solution are presented.

Keywords- energy efficiency; solar energy; lighting;

I. INTRODUCTION

Environmental pollution is growing with the constant increase in economic activity in developed countries. With pollution increasing, awareness of society that action must be taken to stop the destruction of Earth is growing. There is lack of consciousness about environment or consciousness is only for those people who are always, in life and work "ecologically minded". However, the awareness of the problem is not enough to trigger the activity, although it is a good starting point for improving the existing situation in the field of environmental protection. The warning information on global warming and changes in climate caused by global warming, gathering scientific and professional organizations, which establish policies, procedures, recommendations and publicity campaigns. They are trying to influence the society to change individual behavior towards nature.

Environmental awareness campaigns are not sufficient to encourage people to actions that can reduce pollution. However, there is a "universal driver" for implementation of proper measures and proper treatment of energy and environment in general, and that is money. Most managers speak the "language of money". Success of any energy efficiency project depends mostly on management commitment to energy efficiency improvements. Managers and owners are interested in cost savings and increased profits. If the "language of money" is used in environmental campaigns, there may be significant developments in this area.

The modern age is characterized by the need for additional sources of energy. Sources of energy based on fossil fuels are limited. Sustainable energy sources are underutilized. New technology uses available energy sources more effectively. However, there are still old technologies and equipment which use energy inefficiently and which are not environmentaly friendly. Maintaining old equipment brings high maintenance costs. Switching to energy sources that are inexhaustible, and whose exploitation is available to all, reduces operating costs and environmental pollution.

Using solar energy for public lighting certainly reduces the power consumption, especially during long winter nights. Solar panels are a good-looking and do not disturb street lighting appearance. In Serbia there are already implemented projects using wind turbines and solar panels for street lighting. This paper describes a specific solution that includes a complete monitoring and management of lighting lamps [2].

II. LAWS AND STANDARDS OF ENERGY EFFICIENCY IN SERBIA

Response to concern about environmental protection and preservation of the planet is certainly a growth of legislation in the field of environmental protection, energy efficiency and renewable energy, in the European Union and in the Republic of Serbia. The road to Serbia's EU accession consists in instituting the legislation (directives and regulations) as a national law and its adequate implementation.

In order to preserve the environment, international organizations have adopted standards and recommendations which help companies streamline their operations to an energy-efficient level and to measure and monitor energy efficiency as the basis for evaluating improvements. Implementation of regulations and standards allows companies to realize significant savings in the long term, to increase energy efficiency and to preserve the environment by reducing harmful emissions. Some of these standards include the European standard EN 16001 which was issued by the European Committee for Standardization and international standard ISO 50001 which was issued in 2011 by the International Organization for Standardization. Motivation for the application of environmental standards are environmental and financial. Although the use of standards and changes in

the modern technology requires initial investments, such solutions in the long term bring significant savings and a positive impact on the environment, and consequently improved business image [2].

Certificate in relation to the requirements of the ISO 14001 standard for environmental management systems were became an essential part of any tender. It will not take much time before standards for energy efficiency become a condition for entering the market and a "tool" to cope with competition. According to the standards, one way to achieve improved performance in energy efficiency is use of "modern" renewable energy sources instead of "traditional" sources that pollute the environment. One alternative energy source, which is often used, is the solar energy [3-5].

In Serbia, the energy sector in general is governed by the following mandatory and voluntary instruments:

- Energy Law,
- Development Strategy of the Republic of Serbia by 2015,
- Program for realization strategy for energy sector of Serbia 2007-2012,
- First action plan for energy efficiency of the Republic of Serbia for the period since 2010 to 2012.

Speaking specifically about energy efficiency and use of renewable energy sources, in the Republic of Serbia the following regulations and voluntary instruments are adopted:

- Regulation on conditions for acquiring the status of privileged power producers and the criteria for assessing the fulfillment of these conditions,
- Regulation on incentives for the production of electricity, using renewable energy sources and combined heat and power,
- Law on Construction,
- Regulation on the conditions, content and manner of issuance of certificates of energy performance of buildings,
- Regulations on energy efficiency in buildings [6].

In the Republic of Serbia a Law on rational use of energy [7] is currently in draft form. This and other laws provide the minimum requirements that a business entity must meet to avoid violation of the provisions of the law and to avoid paying fines. Law on the rational use of energy (draft) is primarily intended for large consumers and producers of energy. They are the target group and have a legal obligation to maintain an energy management system.

The law is obligatory for all organizations to which it relates, while standards have voluntary application for all organizations. The standard was built on the basic global settings prescribed by law and allows companies to apply it to achieve leadership in the field of energy efficiency.

The provisions of the Law are mainly related to regular monitoring and reporting of energy performance, i.e. reaching the optimal level of energy efficiency. Consequently, the aim of monitoring the energy efficiency in the Republic of Serbia refers to specific environmental parameters, including the energy efficiency. The Law establishes the legal framework and details roles and responsibilities for achieving energy efficiency at the state level.

III. ENERGY POTENTIALS AND THEIR UTILISATION IN SERBIA

Serbia, as part of a global energy network, has excellent qualities for use of solar energy as a single source of energy. Use of solar energy increases economic independence, encourages development and innovations in industry, it is a great opportunity for training new staff and development of new jobs.

According to the data of the Meteorological and Hydrological Institute in 2010, the total annual duration of sunshine hours for Serbia varies in the range of 2011.1h (Kikinda) and 1494.9h (Pozega), while radiation, due to its favorable geographical area, is average 15h in summer, and daily 9h in winter (for Belgrade is 2071h per year) [8-11].

IV. ONE SOLUTION FOR ENERGY-EFFICIENT STREET LIGHTING

The need for lighting every part of the city or town, on one hand, and saving electricity, on the other hand, has stimulated the development of the project of using solar energy in lighting.

A set of devices that will use the energy obtained from solar panels was proposed to power street LED lamps. At a time when the solar panel collects energy of sunlight there is no need for street lighting. All available energy is used to charge the battery. If we want a solution that is successful, we use high-quality batteries and allow adequate charging. Appropriate battery charge involves the use of the battery charger that meets IUU feature. Satisfying the constant voltage and current regime allows the maximum use of battery capacity with longevity prescribed by the manufacturer of the battery. At a time of weak daylight LED lamp is powered by batteries.

The concept is that under the project we implemented a complete solution with an emphasis on energy savings in lighting and reliability of the system LED-DN. The essential element of the system is a device for remote monitoring and control. Using the remote control we can detect easily irregularities in work lamps. The number of lamps in cities is growing, because od that setting the parameters of lamps would not be possible without a remote control device.

System applied for power LED light, called LED-DN, consists of a set of devices:

- LED lighting, solar panel,
- Battery,
- Charger, MN-S
- System for remote monitoring and control SDNU-R.

LED lighting, intended for the project, has power ≈ 30W with dc-dc converter,it is built in luminaires, powered LED diodes in accordance with their characteristics.

The solar panel is a source of energy, and the size and power depend on the type of lamp that needs power. Selected solar panel power is ≈ 200W, optimum operating current I (A) ≈ 10A with optimally operating voltage 17V ≈ (28Vmax).

The battery is selected in accordance with the selected solar panel. The battery must have sufficient capacity to maintain the operation of lamps at night in the winter period when the brightness is at minimum. On the other hand, the battery must match dimensionally for instaling close to the solar panel and LED light. Manufacturers of batteries have developed a special type of battery that allows a large number of charges and discharges. Battery which, according to the manufacturer, allows a minimum 5 000 charges and discharges is chosen for the proposed solution. This battery, with a daily charge and discharge lifetime can be used about 10 years.

Selected battery charger MN-S is used to charge the batteries at a time when the solar panels receive enough light. It has a controlled current and voltage of charging, i.e. meets the IUU battery charging feature. In current mode, the battery is charging with constant voltage until reaches its preset value of charge *Uboost*. After that, the next step is in voltage mode where the current decreases slowly and after a while the voltage exceeds the value of voltage of maintaining the battery *Ufloat*. The charger has a built-in MPPT (Maximum Power Point Tracking) algorithm, PWM control and temperature compensation. Adjustable parameters allow customization of the different types of batteries. Each charger has built-in protection from overcharging of batteries.

SDNU-R system is designed to monitor and control LED lighting. Monitoring of lighting is a control of the current and voltage of battery. It also monitors the operation of lamps in the event of activation of alarm for irregularity situations. SDNU-R system consists of the following units:

- Peripheral monitoring unit
- Communication module for remote communication
- Central monitoring unit

Fig. 1 shows a block diagram of the components of the LED-DN system .

Peripheral monitoring unit means a device for collecting data DNU-R. The unit has a built-in microcontroller to read and store data, 8 analog inputs and 4 digital outputs/inputs.

Analog device measurings DNU-R are:

- battery voltage,
- LED lamps voltage,
- battery current,
- temperature,
- intensity of illumination,
- reference values (voltage and current) of battery charger.

In addition to six measurements defined on the device, there are two spare inputs for measure on customer requirement. Anticipated measured values, too, can be adapted to customer requirements.

Digital devices signal DNU-R are:

- switching on of the battery (under voltage protection),
- turning on of lights,
- motion sensor,
- antivandal signal.

Selected digital signals are adjusted to monitoring of lights, but if necessary can be changed. An important signal called to antivandal signal alarm in case of damage or theft lamp batteries [2].

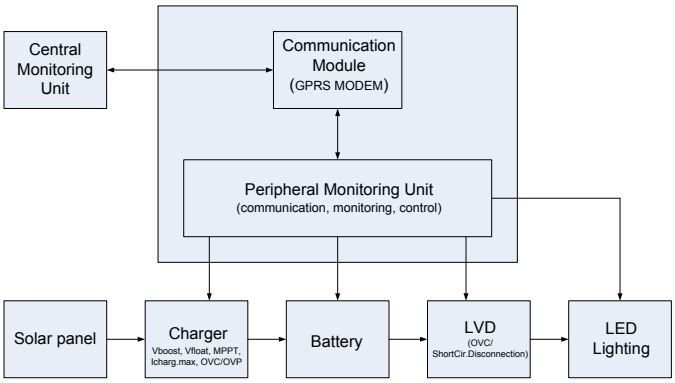

Figure 1. Block diagram of the connection of components in the system.

V. INITIAL STEPS IN IMPLEMENTATION OF PROPOSED SOLUTION

The proposed solution of using solar energy to power street lighting contains a number of details. One must to pay attention when implementing the project. Devices that have been selected by their function suit lighting project, but need to be controlled and to ensure its reliability. Selected remote monitoring system SDNU-R has developed in hardware and software to provide maximum control of lamps and protect data transfer. Communication protocol for system SDNU-R is a local (SDNU) protocol.

System for remote control uses either local protocol of used system or SNMP. SNMP is a standard protocol for the management and administration of the network that is used to collect information about online subjects and then send to the administrator. If LED-DN need main center for the control (NOC) during using the system, SDNU-R can be adapted to the data transfer using SNMP. With a simple software add-ons required information will be submitted to a higher hierarchical level, in the standard SNMP format.

Software in the peripheral monitoring device unit DNU-R collects measured values of LED lighting and forwards it to central monitoring unit, using the communication module. Measurements are read every second and stored in memory processors DNU-R. Every 15 minutes, the central monitoring unit calls the peripheral monitoring unit and take the last measured value. In the event that any measured data is out of the range of allowed values, in DNU-R, it appears to central monitoring unit and sends an alarm [12].

If the remote control is not being used, sensing the measured values can be made by direct access to the device DNU-R using laptop. In this case, the responsibility of the user is to periodically (every 72 hours) load stored data.

Communication module for remote communication, associated with peripheral monitoring unit, enables remote communication via GPRS. Using communication module, measured values are transmitted to a remote central monitoring unit.

The central monitoring unit consists of a computer that contains a Graphical User Interface application (GUI). LED lighting project, for now, includes the city of Belgrade so that the computer sees the monitoring of the territory of Belgrade with marked locations where the system LED-DN is mounted. In Fig. 2 is an example of basic graphic display. Green circles indicate the positions (line of lights) on which the system LED-DN is mounted. In the event that any SDNU-R detects an abnormality, the green circle will be colored in red. In this way, the user knows that alarm appeared on a some site.

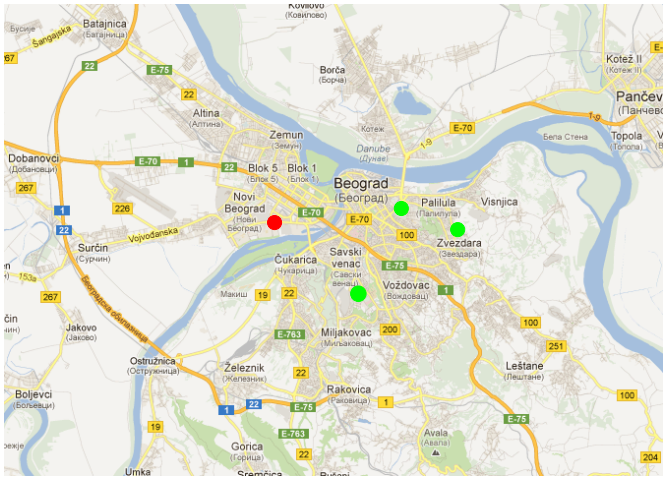

Figure 2. Basic graphical representation (map of Belgrade).

When marked circle is activated, a table that contains a list of luminaries on one line opens. Fig. 3 shows an example of a line of lamps monitored by system LED-DN. The lamp that is "in alarm" will be highlighted in red.

Lights which are marked in blue are switched-off or have status OFF. Activating any lamp from the list opens a graphic display selected LED lamps. In Fig. 4 is an example of a graphic application for one lamp. It clearly shows the measurement of each LED lamp (voltage, current and temperature of the battery, the voltage of the LED lights, the intensity of illumination, the voltage and current of the battery charger) and digital signals. Battery and lamp have the ability to remotely turn on and off. This type of control signals can not be activated without placing a pre-arranged code.

Linija ZVEZDARA

Redni broj	Oznaka svetiljke	nadzor	status	Redni broj	Oznaka svetiljke	nadzor	status	Redni broj	Oznaka svetiljke	nadzor	status
1	01-LED-007	LED-DN	ON	34	34-LED-007	LED-DN	ON	67	67-LED-007	LED-DN	ON
2	02-LED-007	LED-DN	ON	35	35-LED-007	LED-DN	ON	68	68-LED-007	LED-DN	ON
3	03-LED-007	LED-DN	ON	36	36-LED-007	LED-DN	ON	69	69-LED-007	LED-DN	ON
4	04-LED-007	LED-DN	OFF	37	37-LED-007	LED-DN	ON	70	70-LED-007	LED-DN	ON
5	05-LED-007	LED-DN	ON	38	38-LED-007	LED-DN	ON	71	71-LED-007	LED-DN	ON
6	06-LED-007	LED-DN	ON	39	39-LED-007	LED-DN	ON	72	72-LED-007	LED-DN	ON
7	07-LED-007	LED-DN	ON	40	40-LED-007	LED-DN	ON	73	73-LED-007	LED-DN	ON
8	08-LED-007	LED-DN	ON	41	41-LED-007	LED-DN	OFF	74	74-LED-007	LED-DN	ON
9	09-LED-007	LED-DN	ON	42	42-LED-007	LED-DN	ON	75	75-LED-007	LED-DN	ON
10	10-LED-007	LED-DN	ON	43	43-LED-007	LED-DN	ON	76	76-LED-007	LED-DN	ON
11	11-LED-007	LED-DN	ON	44	44-LED-007	LED-DN	ON	77	77-LED-007	LED-DN	ON
12	12-LED-007	LED-DN	ON	45	45-LED-007	LED-DN	ON	78	78-LED-007	LED-DN	ON
13	13-LED-007	LED-DN	ON	46	46-LED-007	LED-DN	ON	79	79-LED-007	LED-DN	ON
14	14-LED-007	LED-DN	OFF	47	47-LED-007	LED-DN	OFF	80	80-LED-007	LED-DN	ON
15	15-LED-007	LED-DN	ON	48	48-LED-007	LED-DN	ON	81	81-LED-007	LED-DN	ON
16	16-LED-007	LED-DN	ON	49	49-LED-007	LED-DN	ON	82	82-LED-007	LED-DN	ON
17	17-LED-007	LED-DN	ON	50	50-LED-007	LED-DN	ON	83	83-LED-007	LED-DN	ON
18	18-LED-007	LED-DN	ON	51	51-LED-007	LED-DN	ON	84	84-LED-007	LED-DN	ON
19	19-LED-007	LED-DN	ON	52	52-LED-007	LED-DN	ON	85	85-LED-007	LED-DN	ON
20	20-LED-007	LED-DN	ON	53	53-LED-007	LED-DN	ON	86	86-LED-007	LED-DN	ON
21	21-LED-007	LED-DN	ON	54	54-LED-007	LED-DN	ON	87	87-LED-007	LED-DN	ON
22	22-LED-007	LED-DN	ON	55	55-LED-007	LED-DN	ON	88	88-LED-007	LED-DN	ON
23	23-LED-007	LED-DN	ON	56	56-LED-007	LED-DN	ON	89	89-LED-007	LED-DN	ON
24	24-LED-007	LED-DN	ON	57	57-LED-007	LED-DN	ON	90	90-LED-007	LED-DN	ON
25	25-LED-007	LED-DN	ON	58	58-LED-007	LED-DN	ON	91	91-LED-007	LED-DN	ON
26	26-LED-007	LED-DN	ON	59	59-LED-007	LED-DN	ON	92	92-LED-007	LED-DN	ON
27	27-LED-007	LED-DN	ON	60	60-LED-007	LED-DN	ON	93	93-LED-007	LED-DN	ON
28	28-LED-007	LED-DN	ON	61	61-LED-007	LED-DN	OFF	94	94-LED-007	LED-DN	ON
29	29-LED-007	LED-DN	ON	62	62-LED-007	LED-DN	ON	95	95-LED-007	LED-DN	ON
30	30-LED-007	LED-DN	ON	63	63-LED-007	LED-DN	ON	96	96-LED-007	LED-DN	OFF
31	31-LED-007	LED-DN	ON	64	64-LED-007	LED-DN	ON	97	97-LED-007	LED-DN	ON
32	32-LED-007	LED-DN	ON	65	65-LED-007	LED-DN	ON	98	98-LED-007	LED-DN	ON
33	33-LED-007	LED-DN	ON	66	66-LED-007	LED-DN	ON	99	99-LED-007	LED-DN	ON
								100	100-LED-007	LED-DN	OFF

Figure 3. Representation of a list of one-line LED lights.

Pressing the button *Specifications* which is located on the square of solar panels and batteries, you can get the detailed characteristics of the used panels or batteries.

Pressing the button *Setup* opens the window shown in Fig. 5. In the shown window, user enters the parameters of battery charger, which after activation the button *Parameters entry* and typing certain codes, are sent to the peripheral monitoring unit, and then to battery charger.

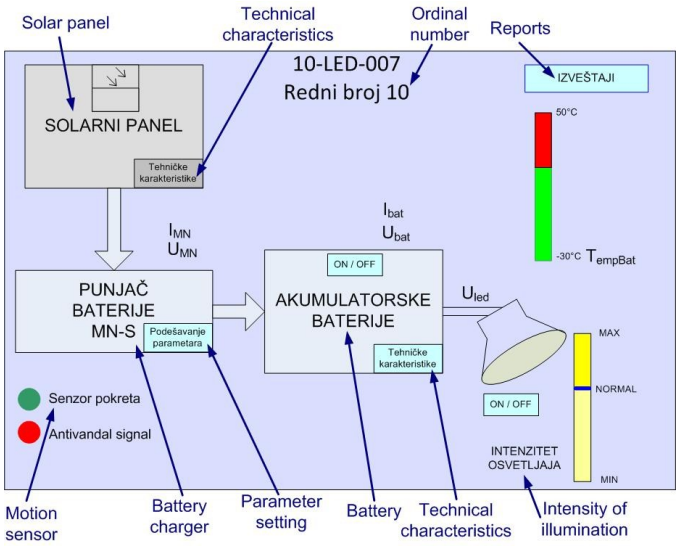

Figure 4. Basic graphical representation of one lamp.

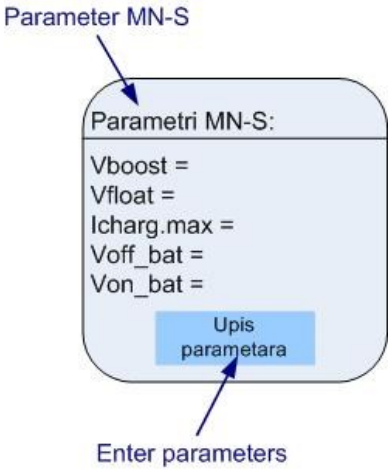

Figure 5. Setting the parameters of MN-S.

All received measured values and status of the digital alarms are stored in the database in a computer of central monitoring unit. At any time, the user can get a record of the measurement in a given period of time. For there to be an insight into the use of the system SDNU-R, any change in parameters or sending control signals will be remembered in the database with the date and time of changes sending. In this time is present analysis of raising security to a higher level, which means that every user of the system SDNU-R must be registered. In this way, it could make a report of alarm occurrence with the name of the dispatcher who received the alarm, or a dispatcher who has changed the parameters of the system LED-DN.

Motion sensor (in the lower left corner of Fig. 4) is a digital signal that can be used in combination with the switching-on of lights. If motion is detected, the lamp is switched-on automatically. In this way, it saves energy accumulated in a time when there are no people near the lamps. Power on/off of LED lighting can be time-triggered by a certain time interval for every third bulb (at a time when there is no motion detection).

An important signal of system, which uses expensive equipment such as solar panels and batteries is *Antivandal signal*. The signal is activated at the moment, for example, cabinet in which is placed the battery pack is opened.

At the time of activation of any alarm, including antivandal signal, the dispatcher receives light and audible alarm. What are the next steps in solving the problem, the system user decides. There is a possibility that after the dispatcher receives the alarm confirmation message, it gets the message whome should inform about alarm occurrence.

VI. CONSLUSION

Conceptual design of the power system using solar energy lamps was created under increasing tendency for energy savings. On the other hand, it encourages more frequent crime affects lighting in each part of the city or small town. As a source of electrical energy, photovoltaic modules are used for charging batteries. Responding Charger meets IUU charging feature which facilitates maximum battery life. LED-DN system has a device for remote monitoring and control, which can monitor the lights.

Antivandal signal is essential in preventing theft of devices. The user receives an alarm on unauthorized access to devices and can react in several ways. Open question accompanying feature of the system is set up cameras that can be an important element in combination with antivandal signal or signal movement. The specific stps to prevent vandalism of these or similar systems must be established with the Police Department.

By using alternative energy sources, a completely independent lighting, supplied individually can be designed. It does not rely on the power grid, and results in cost savings. Additional monitoring and control increases efficiency and reliability of lighting lamps.

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