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# IMPLEMENTATION OF AUTONOMOUS SOLAR SYSTEMS FOR POWER SUPPLY OF TRANSPORT FACILITIES

**Aleksandar Stjepanović, M. Sc.**
**Miroslav Kostadinović, M. Sc.**
**Faculty of Transport and Traffic Engineering Doboj**
**Vojvode Misica 52, Doboj**
**Bosnia and Herzegovina**

**Ferid Softić, Ph. D.**
**Zlatko Bundalo, Ph. D.**
**Faculty of Electrical Engineering**
**Patre 5, Banja Luka**
**Bosnia and Herzegovina**

**Milorad Banjanin, Ph. D.**
**Faculty of Philosophy**
**Alekse Santica 1, Pale**
**Bosnia and Herzegovina**

## ABSTRACT
*The problem with providing electric power to the transport facilities is not rare, particularly when these facilities are located in areas with little or no access to the standard electricity grid. One of the solutions to the problem of providing electricity supply to the transport facilities lies in the utilization of autonomous solar systems as self-sufficient, standalone power supply systems. For this reason, the work proposes a solution for the autonomous solar system aimed at providing power supply to a multimedia based bus stop, a facility which represents an integral part of the transport infrastructure. To control the key parameters of the solar system at the bus stop, a PIC microcontroller was used; a multimedia tablet PC was employed both for the communication with a central monitoring system and for the interaction with bus stop users. The exchange of information between the bus stop and central monitoring system was performed using GPRS technology.*

**Keywords:** Solar Bus Stop, GPRS, PIC microcontroller, Intelligent Transport System

## 1. INTRODUCTION
The supply of electricity to the transport facilities (lighted signs, parking meters, bus stops, message boards) located in inaccessible places is often a big problem. Use of an alternative, renewable energy source in the form of solar radiation represents a solution capable of meeting the environmental requirements and providing an off-grid supply of electricity [1]. If we consider the maintenance issue of such systems, these solutions are almost ideal because the aforementioned systems require little to no maintenance, and the performance warranty for photovoltaic modules often exceeds 20 years. Compared to systems based on diesel generators that require constant maintenance, the proposed system based on a photovoltaic module has a number of advantages.
In this paper, we propose a system for power supply of the bus stop, a facility which forms part of the transport infrastructure as well as of the ITS (Intelligent Transport System) used for monitoring and supervision of the public transport bus services. Functions for interaction with users via an integrated touch screen tablet PC, functions for power supply of the multimedia billboards, and a function for recharge of the users' prepaid mobile phones were implemented within the solar-powered bus stop (SBS). The proposed system performs the exchange of information with a central multimedia supervisory system (CMSS) using GPRS technology which is integrated into the tablet PC [2]. The

system enables the user to receive information about the road conditions and bus timetables as well as estimate the time needed for a bus to arrive at the bus stop.

## 2. SYSTEM DESCRIPTION AND OPERATING PRINCIPLES

A power supply module integrated into the solar bus stop consists of the photovoltaic panels that have an adequate power, solar charge controller, battery, AC-DC inverter, and microcontroller device [3]. Figure 1 shows a schematic diagram of the system and its components.

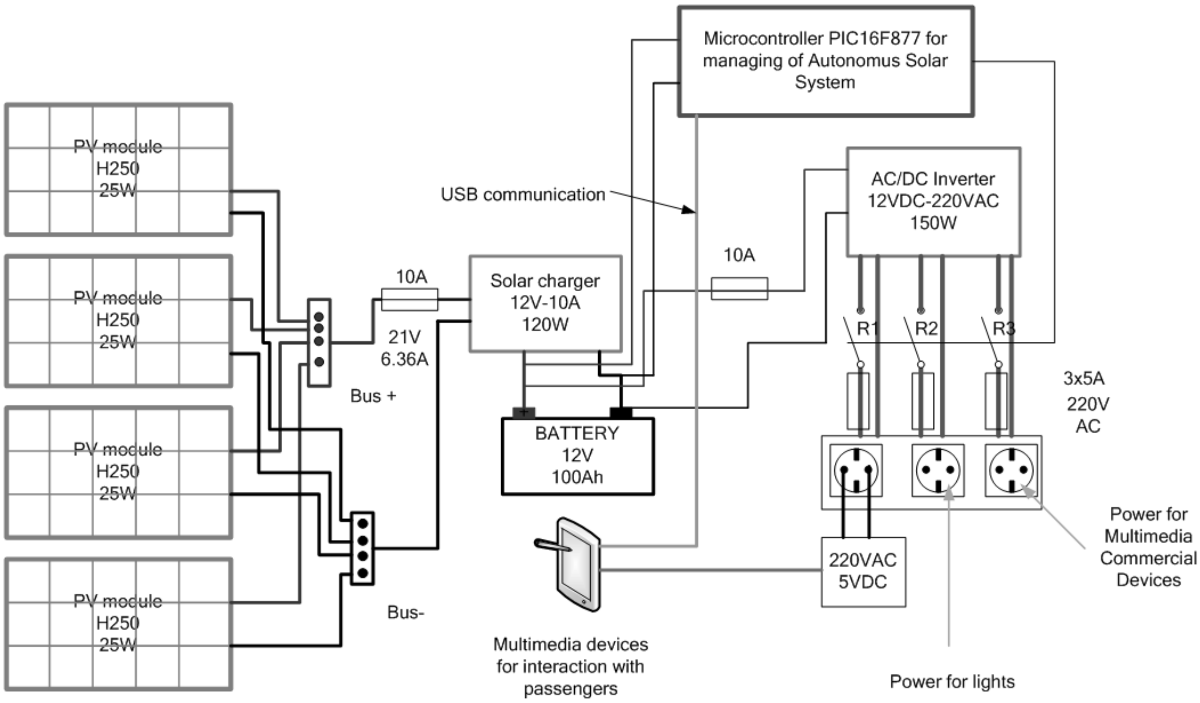


*Figure 1. Autonomous solar system for power supply of the devices integrated into the solar-powered bus stop*

Solar radiation that reaches the photovoltaic modules is converted into electrical energy which is then transferred to the battery by means of a solar charge controller. The AC-DC inverter converts DC voltage (current) of a DC12V battery to AC 220V alternating voltage (current). To monitor the parameters relating to the state of charge of the battery and provide control over the power supply devices integrated into the solar-powered bus stop, a microcontroller circuit based on the PIC16F877 microcontroller was embedded. This microcontroller circuit has the capability of performing AD conversions, and is therefore used to measure the battery voltage and the depth of discharge. Using the relay outputs it controls the supply of power to the consumers, thereby protecting the battery *against* deep *discharge*. All the data gathered about the system through the usage of microcontroller circuit are sent to a tablet PC via a USB protocol**;** using GSM/GPRS technologies, the obtained data are then sent to a central multimedia supervisory system (CMSS). This system is located at the center for monitoring and surveillance of the public transport bus services, where the operator has access to all the information about solar-powered bus stop.

For the purpose of this experiment, a photovoltaic module H250 with the power of 25W was used. Mathematical model of the module employed in this experiment shows short circuit current of PV module $I_{scM}$ as a function of radiation intensity and temperature, which is given by next expression [4]:

$$I_{scM} = \frac{I_{scMr}}{1000} \cdot G + \left( \frac{dI_{scM}}{dT} \right) \cdot (T_c - T_r) \quad \text{... (1)}$$

and open circuit voltage is approximately given by next relation [4]:

$$V_{ocM} \approx V_{ocMr} + \left(\frac{\partial V_{ocM}}{\partial T}\right)_G \cdot (T_c - T_r) + V_T \cdot \ln \frac{I_{scM}}{I_{scMr}} \quad ...(2)$$

where: $I_{scM}$ – short circuit current of module, $I_{scMr}$ – short circuit current of module at reference temperature of $T_r$ =25$^0$C, $V_{ocM}$ – open circuit voltage, $V_{ocMr}$ – open circuit voltage at reference temperature, $T_r$ – referente temperature, $T_c$ – temperature of solar cells and PV module.

Dependence of the output current from the solar radiation intensity, for a constant temperature of the photovoltaic module T = 45$^0$C, is shown in Figure 2.

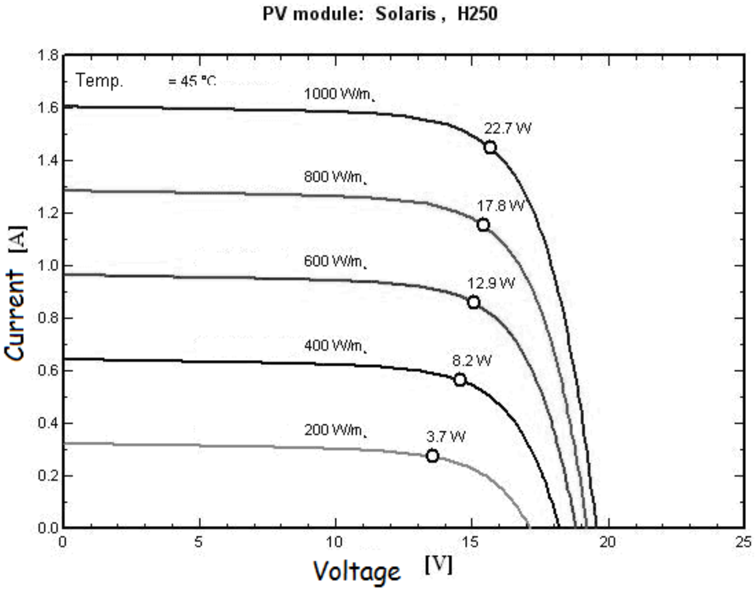


*Figure 2. I-V Module characteristics for T=45$^0$C, G=200 do1000W/m$^2$*

To calculate the operating conditions of the photovoltaic system, a software package PVsyst V6.23. was used. This software package provides an option for the assessment of irradiance as well as the calculation of cost for the entire system based on given parameters. The data that were used as the input had been chosen for the city of Banja Luka; this step was followed by the estimation of solar radiation intensity per month [5] for this city, after which the following consumers were selected:

*Table 1.*

| Consumer | Power [W] | Usage Time [h] |
|---|---|---|
| Lighting | 36 | 5 |
| Advertisement | 9 | 4 |
| Tablet | 1 | 24 |

## 3. EXPERIMENTAL RESULTS

Based on the input data and chosen system components, the information relating to the unused energy (full battery), PV array losses, energy losses for battery charging, and energy supplied to the users over the course of one year were obtained using a software package PVsyst V6.23. A schematic diagram of the obtained results is shown in Figure 3.

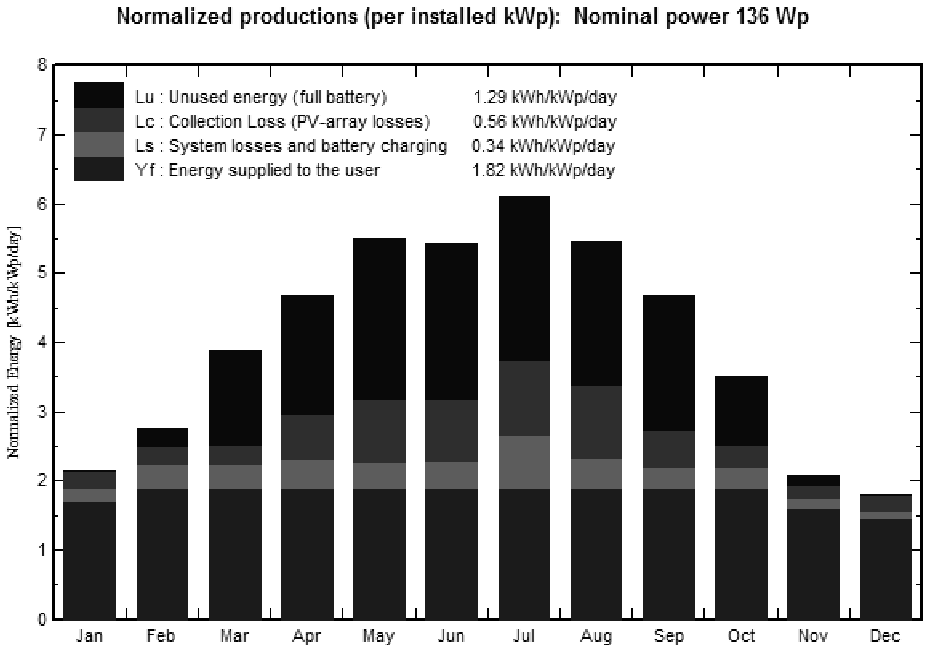


*Figure 3. Energy balance for autonomous solar system integrated into the solar-powered bus stop*

## 4. CONCLUSION

The application of autonomous solar systems for the power supply of the transport facilities has a number of advantages, such as the off-grid usage, low maintenance costs, positive impact on the environment and free source of energy. The paper proposes and describes a power supply system for the solar-powered bus stop that represents an integral part of the system for tracking, monitoring and informing the passengers who use public transport bus services. The aforementioned system is equipped with a microcontroller device used for surveillance and monitoring of the solar bus stop as well as communication with the central system. For the purpose of the systems simulation, a software package PVsyst V6.23. was used; the obtained results show that the proposed system is capable of meeting the needs of the target consumers. Bearing in mind that during the summer months a large amount of energy remains unused while during the months of January and December no excess energy is produced, the worst-case scenario has to be taken into account when designing the system.

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