ENERGY MANAGEMENT FOR PV STREET LIGHTING

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ABSTRACT: The PV modules are ideal for use with batteries for stand-alone systems for street and parks lighting, etc. The energy management unit developed for these systems (PV-panels, batteries and lamp) is performed by a microcontroller system in order to optimise the energy use and the provided lighting service. The control unit (CU) is responsible for the lighting profile and lamp illumination and is programmable according to the needs through a user-friendly Windows communication software. A universal dimmer is responsible for the illumination of the lamp. The work was carried out during the course of the CRAFT-JOULE project "JOR3-CT98-7017".
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1. INTRODUCTION

The penetration of photovoltaic street lighting rapidly increases, especially in low traffic streets, squares, parks, etc. These systems are stand-alone and consisted of a PV panel, a battery, a lamp and a control unit. According to the energy management used, a longer battery life can be achieved resulting in less maintenance costs. Particularly in streets with low night traffic, the use of such systems reduces the energy consumption. For example, a significant low illumination is used and only when a move is detected the illumination increases resulting in an extremely high energy saving. A considerable energy saving can be achieved in squares by setting the illumination of the lamp at 50% late at night, without compromising the effectiveness of lighting. A similar case is the advertising signs where an illumination of 60% can be used after e.g. 2:00 a.m. without having any effect in the visibility of the sign, but reducing the energy consumption by 40%. An energy management, which satisfies the above cases, is developed.

2. HARDWARE DESCRIPTION

The PV Street Lighting System consists of a Control Unit (CU), a charge controller, a universal dimmer, a battery and a PV panel as shown in figure 1. The CU is the heart of the energy management system because it controls the energy of the battery and the way it is spent on the different parts of the system.

The prototype CU is made up of a box consisting of the CPU card, the Power Supply and sensors card. Figure 2, shows the Control Unit box. The installation procedure of the Control Unit is considered to be simple. The prototype Control Unit developed by CRES is based on the Motorola microcontroller MC68HC11F1. The maximum of its resources are: 8 analog inputs, 8 digital inputs, 8 digital outputs and 3 PWM inputs/outputs. The software-controlled power-saving modes make the MC68HC11 family especially attractive for battery-driven applications.

The universal dimmer is capable of switching and dimming all kind of lamps, e.g. incandescent, fluorescent, sodium, iodine, etc.

The charger is responsible for the charging and the protection of the battery while discharging. The operating voltage of the system may be 12 or 24V.

The total consumption of the control unit and sensors is less than 4W.

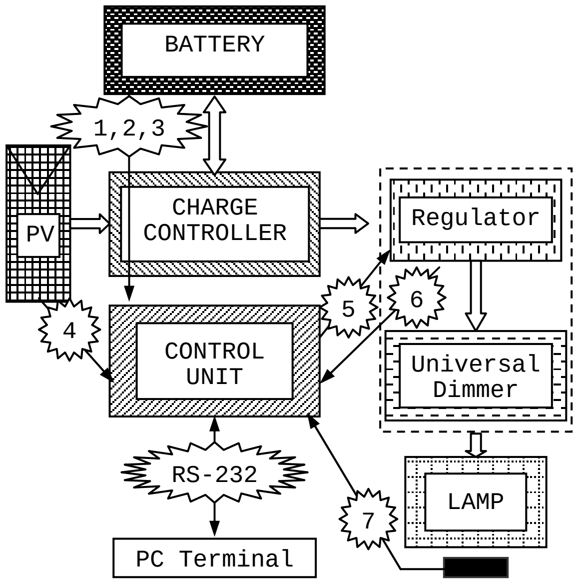

Figure 1: Block diagram of the PV Street Lighting System

Table I: **Monitoring values**

	Description	Type	Measuring range
1	Battery Voltage	Analog	0 - 50Vdc
2	Battery Temperature	Serial	-55 - +125°C
3	Battery Current	Analog	-5 - +5Adc
4	PV Voltage	Analog	0 - 50Vdc
5	Reference output	Analog	0 - 5Vdc
6	Output Voltage of Regulator	Analog	0 - 200Vdc
7	Luminous measurement	Analog	0 - 5000Lux

Figure 2: The prototype control unit

Table I shows the monitoring values of the Control Unit, while table II shows the specifications of the Control Unit.

Table II: Specifications of the Control Unit

FEATURES	SPECIFICATIONS
External Communication	Serial through RS232
Power Supply	9 - 36 VDC
Analog inputs PWM output	- 0 - 5V - Conversion type: Successive approaches - 0-100% (1kHz frequency)
Memory	- 1kB static RAM for temporary storage - 32 kB non-volatile RAM for raw data collection - EPROM for the operational software
Real Time Clock	Real time clock on the CPU card, registering time with the measurements in the stored data files (backed up by a battery with 10 years power autonomy)
Operation Temperature	0 to 70°C
Data File Output	ASCII format (to download data) that can be used with commercial spreadsheets
Sensors (provided with CU)	-LEM Hall effect transducers for Voltage -NT Hall effect transducer for Current -Digital Thermometer for Temperature

3. ENERGY MANAGEMENT

The illumination output of the lamp has four levels of intensity (0%, 30%, 50% and 100%) which are controlled by the output reference of the CU. When the reference is set to 0% then the lamp is off. By having different levels of intensity the best energy saving can be achieved without compromising the effectiveness of lighting. The levels of intensity are programmable and can be ranged at any value between 0 and 100%. The lighting schedule can also be programmed based on lighting demand instead of the prevailing local conditions. The built-in real time clock is responsible for the scheduled operating condition. The default lighting schedule is from dusk to dawn, which is the most common way of operation.

The default lighting schedule is as follows:

At dusk when $V_{pv} < 3.5V_{DC}$ for 60 sec the lighting intensity is set at 30% for 10 minutes, then at 50% for 1 hour and then at 100% for 3 hours. Thereafter, the reference is set at 50% until dawn when $V_{pv} > 9V_{DC}$ for 60 sec or until low voltage disconnect is reached (if V_{bat}<23 V_{DC} then the lighting intensity is set to 30%,if V_{bat}<22V_{DC} then the lighting intensity is set to 0%) as shown in figure 3.

This way the longest time of night operation can be achieved and the battery life can be prolonged since the low voltage disconnect alert prevents the battery from being damaged, resulting in less maintenance costs.

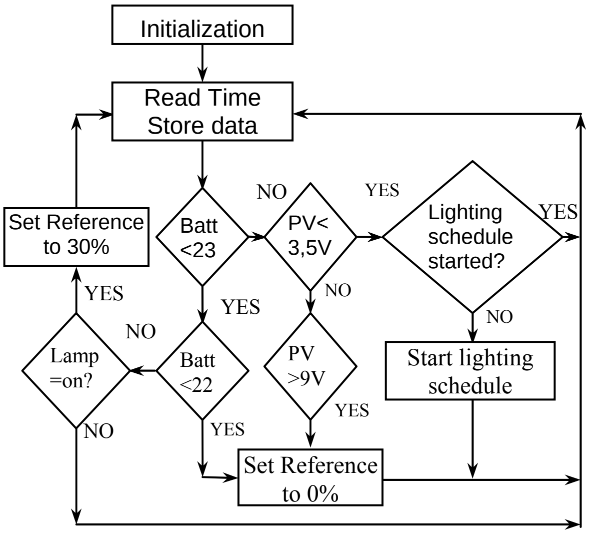

Figure 3: Logic diagram of the Energy management

The universal dimmer is capable of switching and dimming all kind of lamps, e.g. incandescent, fluorescent, sodium, iodine, etc. providing different solutions proportional to the needs.

4. MONITORING AND PROGRAMMING OF THE CONTROL UNIT

The Control Unit monitors the battery voltage, temperature and current, the PV voltage, the luminous of the lamp and the input voltage of the lamp. The state of operation of the lamp is also stored, i.e. in which stage of the lighting schedule the lamp operates.

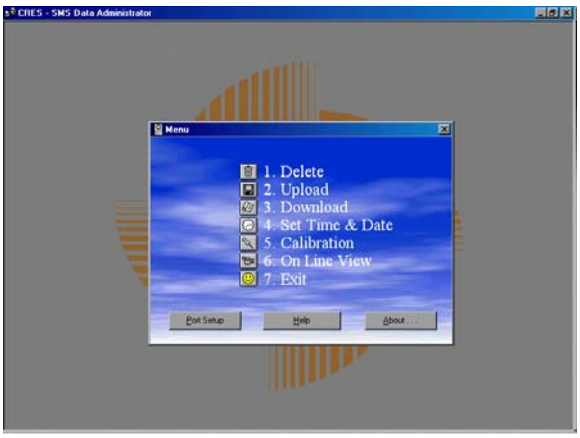

Figure 4: The visualisation software used for monitoring and programming of the Control Unit

By combining the data together, the operating condition of the system can be defined. Data is stored every 15 minutes, which is the mean value of 1-minute measurements except the temperature, which is the moving average of 2 continuous minutes. Data is stored in non-volatile memory together with the time and date, so that the measurements can be corresponded to real time.

The CU is connected to a PC serially through RS-232 for monitoring and reprogramming of operations. By having a cable connected to the CU there is no need of physical access to the CU, which is significant for places that are difficult to approach.

CRES has developed a menu driven software for monitoring and programming the Control Unit that provides user friendly communication between a PC and the CU, which is shown in figure 4.

Each option represents a function and it is activated by two different ways. Either by its number (keyboard) or by pressing the button next to the option (mouse).

The available options are:

1. Delete: Deletes the data collected in CU memory.
2. Upload: A data file is created in the PC, where the collected data is saved.
3. Download: Defines a number of parameters concerning the CU's operations, e.g. customised intensity levels and lighting schedules.
4. Time & Date: Checks and reprograms the time and date kept by the CU's real time clock.
5. Calibration: It applies correction values to the data being uploaded from the CU to the PC.
6. On line view: Displays the measured parameters
7. Exit: Exits the communication program.

On the main MENU the user has also the option to select the communication port (Port Setup button) of the PC being used.

5. THE EXPERIMENTAL INSTALLATION AT CRES

At CRES an experimental PV Street Lighting System was installed in order to evaluate its performance. At the present the simplest case is examined where on/off control is applied to a fluorescent lamp, together with a STEKA charger. A 24V battery was used which was already tested in other experiments.

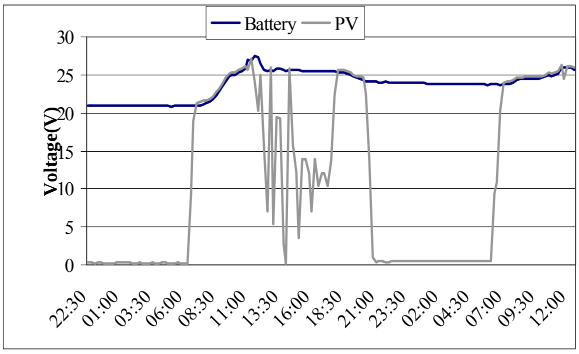

Figure 5: PV and Battery voltage

Figure 5 shows the charging of the battery according to the PV voltage. The fluctuation appearing is due to the charger. When the battery reached its maximum voltage, the PV voltage was cut off to prevent the battery from overcharging. When the battery voltage became low then the PV voltage was turned on again and the charging of the battery started from the beginning. The graph has also this sharp fluctuation because the values displayed are mean values of 1-minute measurements. Figure 6 shows this installed system of the PV street lighting at CRES

Figure 6: The experimental PV street lighting system installed at CRES

6. CONCLUSIONS

Energy management is very important for the PV street lighting system. Bad energy management means a discharged battery, which means less night operation, and greater maintenance costs. A low cost control unit for energy management is developed. It can drive a universal dimmer for a variety of PV street lighting applications.