Automatic System for Solar Panel Cleaning

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Abstract: - The article discusses the development of a prototype automatic system, i.e. an autonomous robot, in our discrete event systems laboratory. This system aims to enhance the energy production efficiency of solar or photovoltaic panels by automating the cleaning process. The project's primary objective is to create a financially affordable solution, as current automatic cleaning systems are tailored for large-scale photovoltaic parks and are prohibitively expensive for individual consumers. Many solar panel users currently rely on companies with specialized human operators for panel cleaning, but this presents challenges such as the lack of a permanent and convenient solution for the customer and risks for the service provider.

Key-Words: - Solar panel, microcontroller, automat system, brushless motor, solar charging, green energy.

Received: May 19, 2024. Revised: November 13, 2024. Accepted: December 15, 2024. Published: December 31, 2024.

1 Introduction

This project, i.e. Automatic System for Solar Panel Cleaning (SPC 01), seeks to introduce an automated solution specifically adapted for common use in homes or buildings focusing on cost-effectiveness and the complete automation of the cleaning process.

The motivation is related to the fact that automatic systems with the aforementioned main purpose already exist on the market designed for large-scale photovoltaic parks, and their prices rise to the level of investment for the companies or enterprises that own such parks, [1], [2], [3].

For the common user of house photovoltaic systems, the most convenient solution is companies that own equipment and have human operators specialized in such cleaning operations at their disposal. Of course, this is not a permanent solution for the customer, and for the operator that offers this service, the operation represents a risk, [4], [5]. The innovative aspect of this project is the re-proposition of an automated solution that currently has application only in huge ensembles, adapted for more common and reduced use such as homes or buildings, [6], [7].

Among the main differences compared to the solutions on the market for solar and photovoltaic panel parks, we have first all the prices, as previously mentioned in the project's purpose and the complete automation of the cleaning process, [8], [9].

Automatic systems designed for photovoltaic parks retain a maintenance and, or, mobility component. They are designed so that a human operator has to move the system from row to row, monitor the end of the operation, and in some cases consider the weather to protect the equipment from rain, hail, snow, etc. In contrast to existing systems which require human intervention for maintenance and mobility, this newly developed system aims to operate independently from human involvement, [10]. It is designed to be mounted onto the user's building structure and can function without water, making it suitable for rooftop installations. Compared with hiring companies for panel cleaning, the automatic system minimizes the need for human intervention and allows the user to initiate the cleaning process with a remote control, [11], [12]. This aspect is given by the fixed structure of the panel configuration on the user's building. In this way, the course of the equipment always remains constant and can be predicted and thus calculated when installing it on the solar panel configuration. An implementation is possible and would not be without benefits, its installation is not cost-effective. As the systems are designed for photovoltaic panel parks at a height within reach of the user, the engineers who design them find it useful and cost-effective to add a device to which a pump could provide a flow of water suitable for cleaning the panels. On a building, this option is more difficult to implement, [13]. Compared to the solutions available at the moment for the user who wants to clean his panels on a building, namely the companies that provide human operators with the necessary skills and equipment, of course, the automatic system proposes a different approach, followed by numerous benefits. The automatic system reduces the involvement of a human operator, who may even be the system owner as there is no need to involve third parties such as companies or others, [13], [14]. Our autonomous robot starts cleaning the photovoltaic panels with a simple command given with the help of a remote control on a free radio frequency of 315MHz. The tasks performed by the robot also do not require the care of the user, as if the cleaning solution were a specialist company. In the remainder of this paper, section II discusses the hardware support of the SPC 01 system, and section III focuses on the software support of the SPC 01 system. Section IV concludes our work and suggests further possible development of it.

2 The Hardware Support of SPC 01

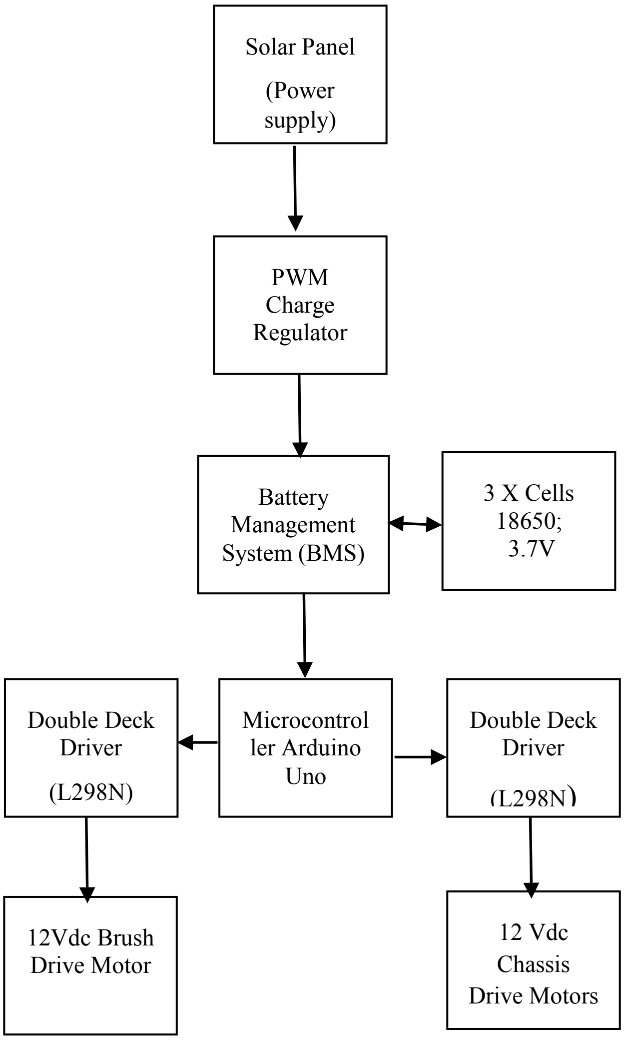

Fig. 1: Block diagram of the automatic solar panel cleaning SPC 01

Depending on the components' roles in the block diagram in Figure 1, the system can be divided into three main parts: the supply side; the control part; and the mechanical part.

Next, the main components of the block diagram will be analyzed to highlight their role.

We mention that the robot is installed on a chassis with telescopic rods compatible with the most used types of solar panels.

Fig. 2: The solar panel, [7]

The solar panel, shown in Figure 2, has many output ports available and can be adapted to several applications. For the purpose assigned in this project, however, the required output is represented by the classic two wires with the positive and negative terminal which will also be the power supply of the battery charge controller, at a nominal voltage of 12V. The battery charge controller performs several functions, as follows:

First, it acts in the system as a voltage step-down: having the input of about 18V from the solar panel, it assigns this voltage only to the battery charge and not to the system's power supply directly.

Secondly, the integrated microcontroller allows the management of all the values at which we want the system to create a connection with the battery, in terms of voltage and the time or scheduled time.

Last but not least, it provides numerous protection circuits that will interface the system with the power supply from the solar panel, among which we find:

- Short-circuit protection;
- Open circuit protection;
- Reverse polarization protection;
- Protection against load current exceeding the system's bearable value.

The method used is PWM (Pulse Width Modulation). The PWM control method involves delivering power to the battery by adjusting the pulse width of a signal. In the context of this project, of charging the battery, a PWM controller reduces the voltage of the solar panel to the level required to charge the battery and maintains this constant voltage by rapidly switching the connection between the panel and the battery. The switching is controlled by the pulse width so that the average voltage applied to the battery is selected with the controller. Among the main advantages of this technique is its simplicity, which leads to low manufacturing costs, at least compared to controllers that use the other battery charging technique on the market, called Maximum Power Point Tracking (MPPT).

Charging module with equalization BMS 3S, 60A, 12.6V is essential because without it the battery cells run the risk of not charging evenly, for example overcharging one cell and not charging another. In addition to this problem of equalization at the time of charging, this circuit also has protection against a deep and uneven discharge of the cells. Two standard values determine both situations: for charging the voltage must not exceed 4.35V per cell, and for discharging it must not fall below 3V per cell. All this monitoring is performed constantly and in parallel on all 3 Li-Ion cells used by this system, Figure 3.

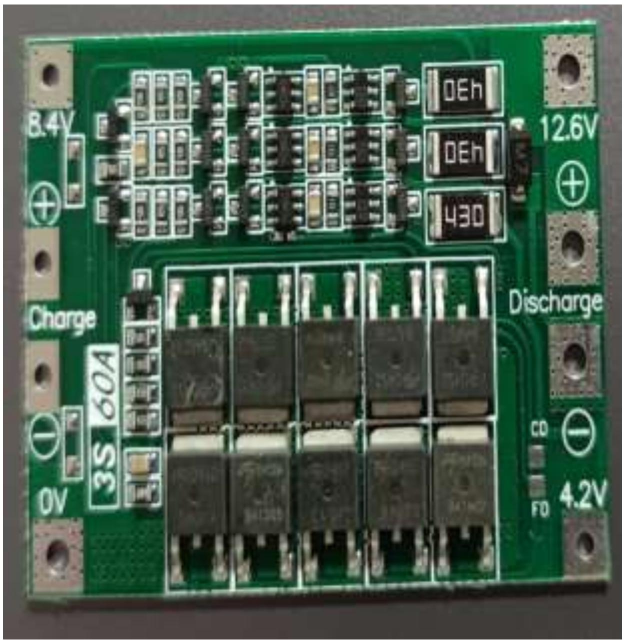

Fig. 3: Charging mode with BMS equalization

Its operation can be briefly explained according to the 3 stages, representing the 3 values of the total voltage of the 3 cells in series. Thus, the first "stage" is completed once the first cells in the configuration series 3S1P or 3S2P (3 Series 1 Parallel or 3 Series 2 Parallel) reach the ideal maximum voltage, i.e. 4.2V. Then it goes to the second cell, the second stage the second value to be checked and reached in terms of cell voltage of 8.4V. The last step will also confirm the battery is fully charged when the total battery voltage, cell by cell, reaches 12.6V.

For batteries, the suitable choice is Li-Ion type cells, mainly because they discharge slowly when not in use and have a long life of up to 1000 charge/discharge cycles. In particular, since the time during which the system is in effective operation is relatively short, the capacity of the accumulators does not need to be very high. The discharge current also does not need to be high, since the entire system consumes at times of maximum load below 1.5A. It turns out that the most suitable Li-Ion cell model choice is 1,8650 Ah type INR -25R.

The system's movement on the solar panel is done with two motors, of the same model, and to avoid load current inconsistency, both motors are controlled by the same L298N double bridge driver. For this reason, the possibility of the same circuit to control the load, in parallel, presents many advantages: reduced space occupied, the possibility of using PWM technology to control the speed of motors, control of motors made easier by the existence of a dedicated library in the Arduino IDE software, and numerous protections for load, including overheating. The motor used in this application is the CHR-GM25-370-12V – 27 RPM brushless motor, with gear, powered at 12V to fit into the system without the need for a step-up, Figure 4.

Fig. 4: The gear motor, DC, CHR-GM25-370-12V 27 RPM

For the composition of the chassis, the dimensions were not followed to be one of the standard ones for solar panels for simple presentation convention. The system can operate in a configuration up to 2m long.

Solid polycarbonate, resistant but also transparent, facilitates the presentation of the project. In addition, various wheels, a brush consisting of a metal pipe and brush, connectors for the motor-wheel connection, and angle connectors for supporting the chassis were also used.

3 The Software Support of SPC 01

The software support, written in Arduino, of the SPC 01 follows the block diagram of the automatic solar panel cleaning in Figure 1. The Arduino programming language is a simplified form of high-level C ++. Arduino is based on an open-source platform, and its development environment implements the Wiring programming framework for microcontrollers. The software used to create the code is available from the Arduino website version 1.8. Next, short lines of code will be presented, which are responsible for the operations mainstream order of SPC 01 system, Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10 and Figure 11.

```
#include <L298N.h>
#include <avr/sleep.h>
#include <avr/wdt.h>
#include <avr/interrupt.h>
#include <avr/power.h>
```

Fig. 5: Library for simplified commands of the L298N driver, and those necessary to minimize electric current consumption

```
int enA = 9;
int enB = 10;
int enC = 11;
int in1 = 8;
int in2 = 7;
int in3 = 6;
int in4 = 5;
int in5 = 4;
int in6 = 3;
```

Fig. 6: Initialize pins for connecting motors

```
L298N motorA(enA, in1, in2);
L298N motorB(enB, in3, in4);
L298N motorC(enC, in5, in6);
```

Fig. 7: Each motor is assigned to the appropriate pins

```
void setup()
{
  motorA.setSpeed(vitezadep);
  motorB.setSpeed(vitezadep);
  motorC.setSpeed(vitezarot);
```

Fig. 8: Set the variables corresponding to each engine

```
while (totalwdt < twentydays)
{
  watchdogInterrupt = false;
  set_sleep_mode(SLEEP_MODE_PWR_DOWN);
  sleep_enable();
  sleep_mode();


  sleep_disable();

  if (watchdogInterrupt)
  {
    totalwdt += 8;
  }
}
```

Fig. 9: Compares the waiting time with the total programmed waiting time

```
motorA.forward();
motorB.forward();
motorC.forward();
delay(4000);
motorA.stop();
motorB.stop();
motorC.stop();
delay(2000);
motorA.backward();
motorB.backward();
motorC.backward();
delay(4000);
motorA.stop();
motorB.stop();
motorC.stop();
```

Fig. 10: Perform panel cleaning, 4 seconds in one direction for all motors, 2 seconds pause followed by 4 seconds reverse and shutdown

The times mentioned in Figure 10 correspond to the dimensions of the solar panel experimented on in the laboratory. Depending on the dimensions of the panels where the robot must be installed, these times will be modified.

```
power_adc_disable();
power_spi_disable();
power_timer0_disable();
power_timer1_disable();
power_timer2_disable();
power_twi_disable();
```

Fig. 11: Disable all peripherals for reduced power consumption

4 Conclusion

An automatic system for solar panel cleaning SPC 01 is a sustainable option for owners of photovoltaic systems who want to eliminate the worry of cleaning solar panels. Even though we tested our robot only in our Discrete Event Laboratory we noticed a dirty solar panel with gray and white spots on 90% of the surface, and cleaned by our robot its yield improved by 23.4%. The software and hardware support of SPC 01 provide a low-cost solution for implementing the digital processes of all components of the robot management and regulatory compliance, for example, but leave room for the inevitable changes that occur in each project. By achieving efficiency, and simplifying the work, it ensures better reliability and preventive maintenance.

This autonomous robot SPC 01 represents a real competitor in solar panel cleaning, through affordable investment, efficiency, and low operating costs according to the IEC 62446-1 standard. SPC 01 system performs the cleaning of solar panels periodically and when significant atmospheric weather occurs without requiring the presence of the property, as well as the lack of disadvantages that appear when the solar panels are cleaned manually.

The future development of the SPC 01 system will deal with cases in which such a system would need to move in two directions, according to the configuration of the solar panels, i.e. cases in which simple left-right movement could be insufficient. At the same time, the long-term reliability of the SPC 01 system must be studied under real operating conditions in the four seasons: summer, autumn, winter, and spring.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed to the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare.