# MECHATRONIC DRIVE SYSTEM FOR CLEANING MACHINE OF PHOTOVOLTAIC PANELS

**PhD. eng. Radu RADOI[1], PhD. eng. Marian BLEJAN[1], PhD. St. eng. Ioana ILIE[1]**

[1] INOE 2000 - IHP, radoi.ihp@fluidas.ro
blejan.ihp@fluidas.ro
ilie.ihp@fluidas.ro

***Abstract:*** *The efficiency of the photovoltaic panels depend on the cleanliness of the reception surface of solar energy. As in time on this are deposited all kinds of impurities, the productive efficiency can drop even up to 50 %. It is necessary from this cause their regular cleaning. The paper presents the structure of the cleaning machine, hydraulic scheme and the mechatronic system based on a unit with microcontroller.*

***Keywords****: mechatronic drive system, pv washing, controller*

## 1. Introduction

The efficiency of the photovoltaic panels depend on the cleanliness of the reception surface of solar energy. As in time on this are deposited all kinds of impurities, the productive efficiency can drop even up to 50 %. It is necessary from this cause their regular cleaning. For this was developed a cleaning machine which required a mechatronic drive system to control his functioning.

***Comparison between systems***

| | **Cleaning Systems** | | | | | |
|---|---|---|---|---|---|---|
| | **1. Manual** | **2.Water jet** | **3.With compressed air jet** | **4.With steam jet** | **5. With sprinklers** | **6. With sliding brush** |
| Efficiency | 80 – 90% | 70 – 80% | 70% | 90% | 70% | 70% |
| Cost/kWh | high | average-high | average | scăzut | mediu | average |
| Water consumption | 6,5÷12% l/m$^2$ | 2,5 ÷ 2,8 l/m$^2$ | - | 0,5÷ 0,6 l/m | 6,5÷12 l/m$^2$ | - |
| Labor | 4÷5 m$^2$/min with 4 operators | 18–20 m$^2$/min with 3 operators | 15-20 m$^2$/min with 3 operators | 22-27 m$^2$/min with 1 operator | - | - |

## 2. The structure of the cleaning machine for photovoltaic panels

The cleaning machine (Figure 1, 6) combines washing system with low pressure water jet (~2 bar) with brushing the photovoltaic panel. The mechanics and kinematics of the machine was developed by the R&D institute ICTCM Bucharest, and mechatronic drive system for hydraulic installation was developed by the R&D institute INOE 2000 – IHP Bucharest. Mechanics of the cleaning machine and related peripheral systems are loaded on a Toyota Hilux utility vehicle. The mechanism incorporates a 180° rotatable pivot driven by a toothed rack - gear wheel type mechanism.The toothed rack is driven left or right by a hydraulic cylinder. At the upper end of the pivot is mounted an arm that has at end a swivel support that is driven through some levers by the hydraulic cylinder **(14)**. Inclination of the arm is made with the hydraulic cylinder **(2)**. Rotating of the brush is provided by hydraulic motor **(32).** On the brush holder are mounted nozzles that

provide washing of the PV with waterjet. The hydraulic cylinder **(2)** performs vertical positioning of the brush to the photovoltaic panel and the hydraulic cylinder **(14)** performs positioning of the brush parallel to the panel. These cylinders must constantly correct vertical position of the brush and angular position because of irregularities of mounting of the panels and due to the irregularities of the terrain encountered on the route conducted by car along of the panels.
On the same utility vehicle is loaded water pump hydraulically driven, hydraulic station for driving hydraulic motors, the combustion engine which act the hydraulic pumps and the water tank for washing.

The heat engine that provides energy for hydraulic station is a 4.5 kW diesel engine with 2200 rev / min.

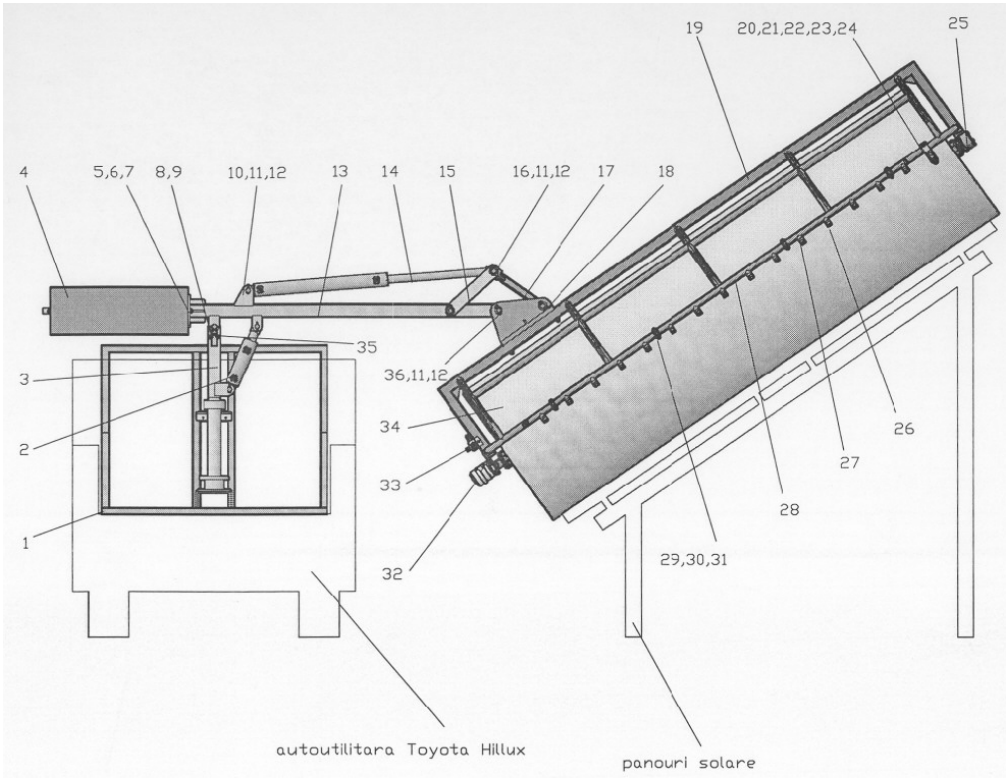


***Figure 1***

### 3. Hydraulic drive scheme

Hydraulic station of which diagram is shown in the figure 2 is composed of:

- Hydraulic tank of 100 l with return filter and oil cooling system. Solenoid valve **(20.2)** turns on or off, depending on the command received from a thermostat, the coolant. Washing water circuit is used as a coolant.
- Pumping group comprising a triple pump driven by a combustion engine of 4.5 kW. The first section of the pumping unit has parameters of 14 l / min and 100 bar feed a pressure bus of which with hydraulic directional valves **10.1, 10.2** and **10.3** are supplied hydraulic cylinders **17,18** and **19** providing vertical positioning of the brush, angular motion or rotating the pivot.

The second section of the pumping group with parameters 4.5 l / min and 60 bar, act through the directional valve **(11)** the hydraulic motor for rotating the brush in direction left or direction right with speed of 125 rev / min.

The third pumping section with parameters 7,5 l/min and 50 bar, act through directional valve **(12** the hydraulic motor for water pump at a speed of 2800 rev / min.

The pressure line for the first pumping section is provided with a hydropneumatic accumulator which is designed to store a volume of about 0.3 l of oil at the stages when its consumers do not consume oil and to restore in the system when its consumers are activated.

A loop of automation based on signals from pressure switches 9.1 and 9.2 download to tank the first pumping section when pressure reaches 120 bar and connect back to the pressure line when the pressure dropped to 90 bar with directional valve (6).

For accidental situation when heat engine is defective in work field, to execute movements for folding the mechanism in the marching position of the vehicle, was set a hydraulic electric pump (26) with parameters of 500 W, 2.5 l / min and 100 bar, supplied from the vehicle's electrical system (12 V).

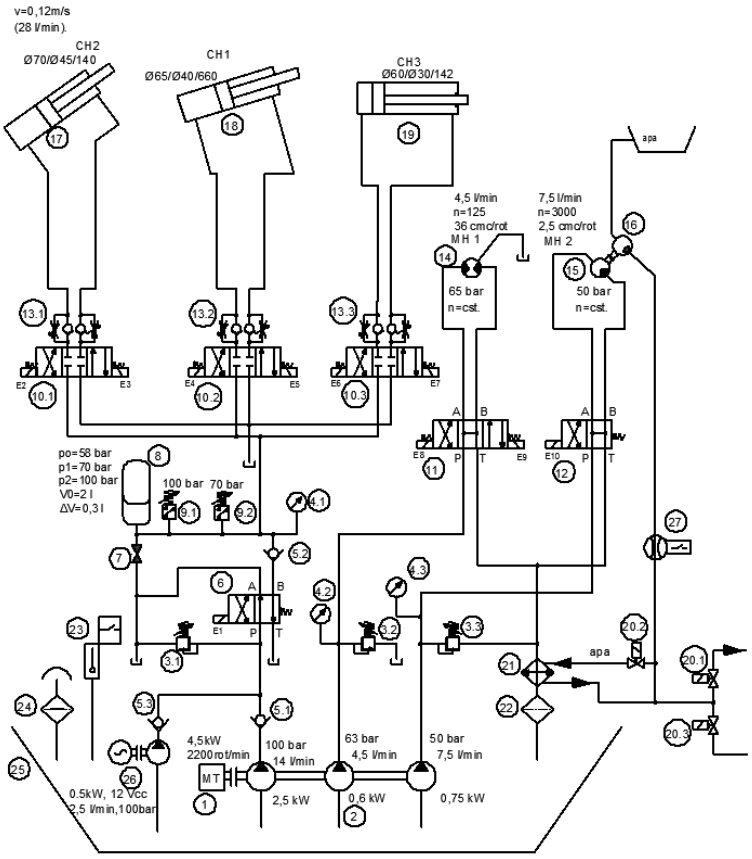


***Figure 2***

## 4. The mechatronic system

Automating of the installation is based on a microcontroller unit that receives information from sensors, from contacts limiter, thermostat and the pressure switches and gives commands to the valves coils for making various movements. Electrical commands are given through high side switches IC's. Commands received by the valves enable a mechanisms movements such as rotating column, arm tilt, brush angle adjustment and controlling valves for washing on the left side, on the right side or cooling circuit. To keep the brush distance from solar panels was implemented a control loop with two ultrasonic distance transducers. The average distance given by the distance transducers from the ends of the brush constitutes the command for positioning the height of brush through the directional valve for arm tilt (Figure 3).The difference of the distances given by transducers on the ends of the brush constitutes the command to directional valve for brush angle, in order to keep distance from the brush to the solar panel. In the figure 4 can be seen the box with controller module, and in figure 5 the remote control unit which permit to the operator to control the cleaning installation.

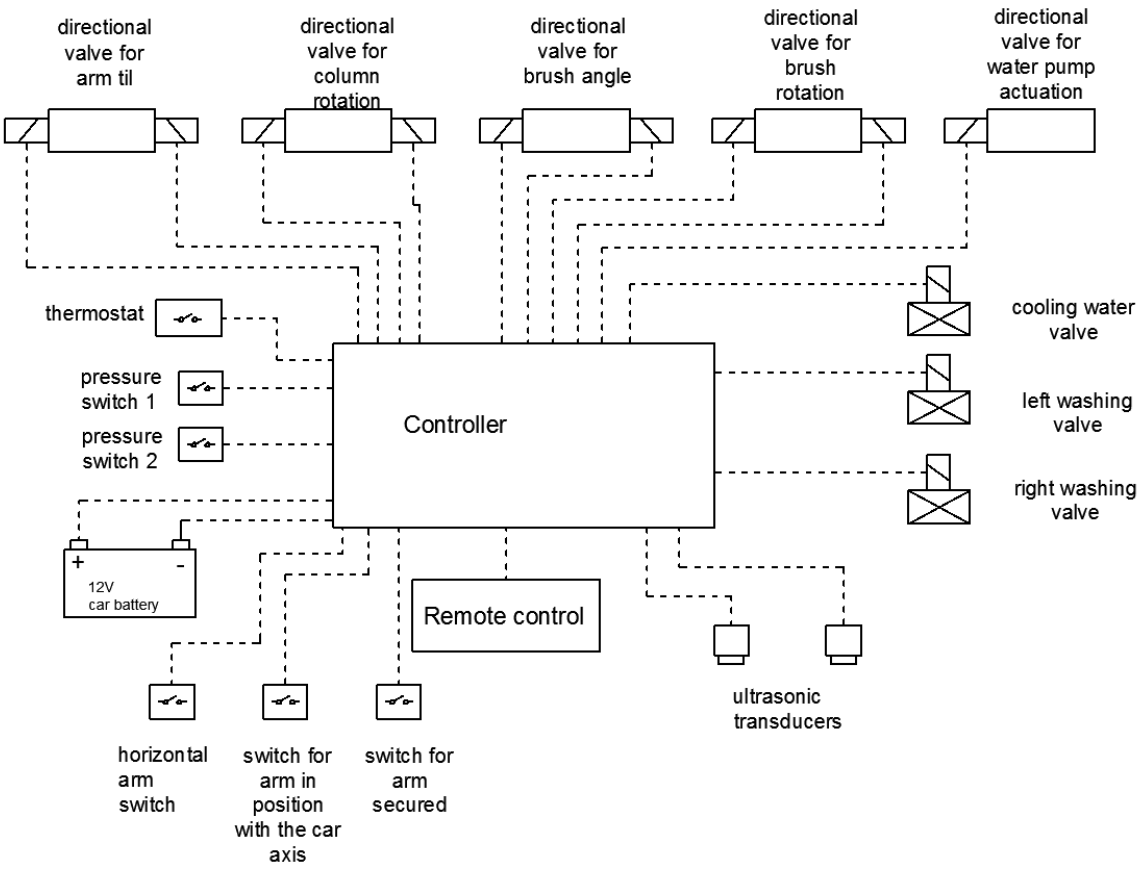


***Figure 3***

***Figure 4***

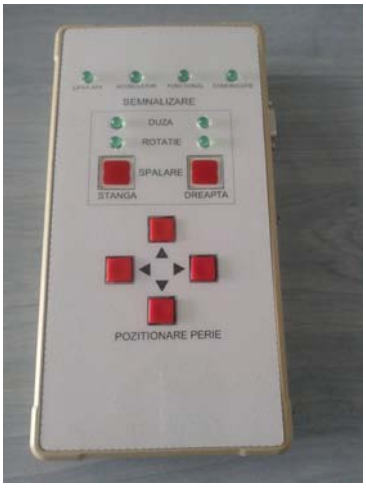


***Figure 5***

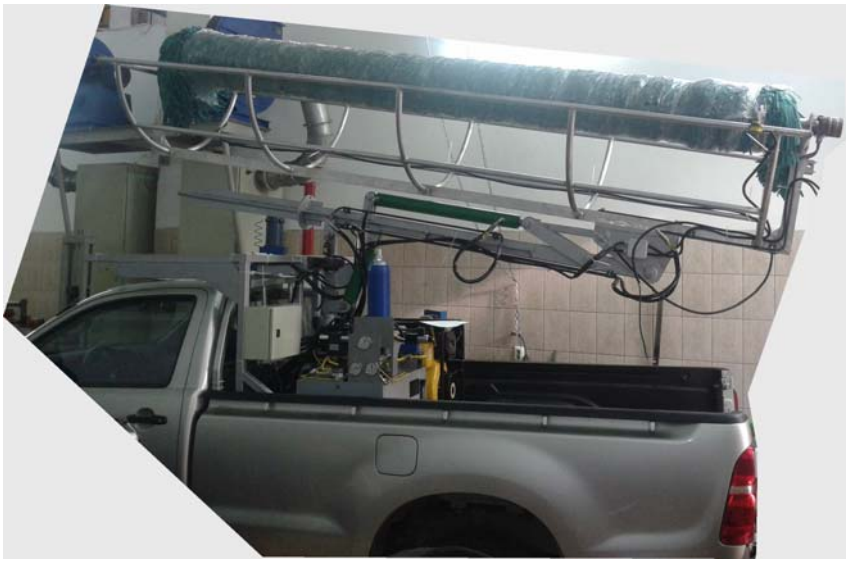

***Figure 6***

## 5. Conclusions

The project is very complex and required design in terms of kinematics, hydraulics and mechatronic systems.
The washing machine for solar photovoltaic panels is the first of its kind being developed in the country and is in prototype stage.
Experiments are underway to carry out adjustments and determine technical performances.

## REFERENCES

[1] Sami Al-Ghannam, Comparison Analysis on Different Cleaning Technologies for Photovoltaic Panels of Utility Scale Application, Saudi Aramco Study pdf, 2012
V. Marin, R. Moscovici, D. Teneslav, Sisteme hidraulice de reglare automată – Probleme practice, Editura Tehnică Bucureşti, 1981
[2] G. Rădulescu, R. Rădoi, I.Duţu, Complex systems for electrohydraulic drive mechatronic, Caciulata, Romania; 7-9 November, 2009, "Proceedings - HERVEX", ISSN 1454-8003; pp.182-187
[3] http://www.solar-facts-and-advice.com/solar-panel-cleaning.html
[4] http://www.ipceagle.com/products/solar-panel-pure-water-cleaning-system#.VEeGzhbHRjU
[5] http://www.bitimec.com/bitimec_page.asp?IDProdotto=315
[6] http://www.saudi-sg.com/2012/files/B42.pdf