IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 5 (May. 2019), ||S (VII) || PP 06-11

"Development of Cleaning Machine for Photovoltaics Plant"

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Abstract

Growing interest in renewable energy has led the solar photovoltaic industry to expand notably in the last decade. However a big issue that is often overlooked too easily, is keeping the panels clean. Panels are often difficult and dangerous to reach and not worth the risk cleaning them. Furthermore, autonomous cleaning machines are often only economical on a larger scale due to both installation costs and the fact that custom-made parts are needed to fit the plant.This papers focus is on finding a more cost-worthy solution for the drive principle in order to de-crease the overall price of the machine, thus making it profitable on smaller scaled PV-plants. The goal is for it to return its investment in two years (being the warranty period in most European countries) while keeping an average family sized plant clean. A principle, were a machine uses two wires attached to the edges of the roof, was investigated. This driving principle was virtually modeled to simulate its performance. Afterwards a proof of concept was built to validate the model.The research found that this drive principle is a promising alternative when applied to small plants. The system is both agile, flexible and very cost effective. According to a rough estimation, for an average family, the machine would earn its price back in two years at losses of 15%. Bigger sized plants return their investment at even lower losses. The reliability has to be improved though.

I. Introduction

The biggest factor that makes up the cost of a cleaning robot is the drive system. Cleaning robots are most commonly installed on rails along the panels. These make the installation relatively ex- pensive for two reason. The first reason is the obvious fact that more material costs more money. All parts are machined and often are built to purpose, in order to fit a specific plant. The second reason is the labour costs for installing the track system to the installation.

Apart from rail based robots, there are other solutions for cleaning panels like sprinkler systems or robots driving on caterpillar tracks made from suction cups. However, these solutions lack both flexibility and cost effectiveness to be applied on a smaller scale.

The logical next step is to look for a more adaptable and economical drive principle for the robot to translate itself over the panels. A concept then has to be investigated on the different design criteria that come along with building such a robot.

The robot has to be able to handle all the forces involved with moving it and this for the different angles at which solar panels can be installed. The driving principle has to be modeled in order to make sure the demanded criteria are met and to simulate its behaviour on a commonly sized installation. Later on, a physical proof of concept is made in order to validate the model and to grasp of how it would work in real life.

The last part of the paper focuses on applying the drive principle to a concept that shows how it could work in real life and to point out the strengths and weaknesses of the system. Also a rough idea of the price and returns are given.

The research of the thesis was done during an abroad semester at Technische Hochschule Nurn¨-berg and execut ed at their 3D visualisation centre.

Fig. Actual View Of The Project

In this chapter a brief theoretical background will be given in order to define the problem. First the focus will lay on the working of the photovoltaic cell. Next this chapter will go deeper into the mechanisms of soiling and degradation as it is important to know what has to be done for cleaning purposes. Lastly there will be a brief comparison of existing cleaning robots pointing out their weaknesses and strengths.

Working principle

When a photovoltaic cell is exposed to sunlight it absorbs the photon's hitting the semiconducting materials. Electrons are excited and move up to a higher molecular or

atomic orbital. To dissipate the extra energy, the electron can either go back to it's original orbital, converting the excess energy into heat, or it can travel through the material to an electrode, thereby cancelling the potential. Regardless of the size, a cell will generate roughly 0.45 volts DC. This implies that the available power generated by the cell will be strictly dependent on the area of the cell that is irradiated by the sun and the material used for the absorption of the photons. To reach higher voltages, cells are installed in series. The types of cells that are commercially available today can be divided into 3 main groups [2]:

Crystalline silicon cells: by far the most used bulk material for PV cells.

Thin Film cells: heavier but have a smaller ecological footprint.

Multijunction cells: still experimental, originally only used in space but terrestrial solar concentrators make them effective on earth now as well.

According to the Flemisch government the installation cost for 1kWp is on average 1700 euro (6% VAT included). As we know from figure 2.1 1kWp delivers 960kWh/year which means that a system generating 3500kWh would cost roughly 6600 Euro. Given the current electricity price the investment should pay itself back in around 11 years.

II. Conclusion

Although, at first glance losses caused by soiling don't seem to have a huge impact on the cell's efficiency, they are easy to minimize by cleaning panels at an economically optimized frequency.

Predicting the exact profit of cleaning the panels regularly is as of today still difficult. It depends on many factors of which precipitation and the presence of pollutants are the most important. This can only be estimated using statistical data.

Existing robots focus mainly on large arrays and are in general heavy and unsuitable for installing on smaller arrays i.e. residential roofs. Only a sprinkler system has the ability to operate profitable at a residential scale but this only in sandy dry areas. In areas like these it might not always be tolerable to use this amount of water.

Existing cleaning robots

The cleaning of PV arrays is mostly done on large scale with big and heavy, custom made machinery. They generally focus on cleaning as many square meters in the least amount of time and often require an operator. The following list focuses on robots that are relatively smaller and don't need an operator.

1Solarbrush

The Solar brush is a light-weight, autonomous robot for dry cleaning solar panels or glass in dry environments. Using tracks made o suction cups, it moves over the panels making it possible to cross gaps up to 30mm and working on surfaces tilted up to 35 degrees. Different kind of brushes can be attached to the front of the robot in order to brush away dust, sand and dirt. Power comes from a rechargeable battery

Figure The solar brush robot without it's brush.

Wash panel systems

An Italian company called 'Wash Panel' produces robots that clean arrays of PV panels by moving a vertical brush horizontally over a row of panels. Having a length of 1 to 16 meters and containing a 12V battery it can be deployed automatically. Also a water hose is attached for wetting the panels while cleaning. However the robot rather doesn't need a track like most panels have.

Manual cleaning

Technically this is not a robot but as this is the one of the most used ways of cleaning residential solar panels today it therefore important to mention as well. Using a so-called water fed telescopic pole and a special non scratching brush, the panels gets cleaned manually. Standing on ladders or climbing on roofs, this is often a job for a professionals as it is risky and requires the right material. However as mentioned in section 2.2.1 this method might have little or no influence on the yearly yield unless it gets done regularly. Especially if the job is done by a contractor this might be very bad investment there the labor costs will exceed the profitable return.

Figure : A person cleaning PV panels manually with water fed pole.

Goals

Before starting the design phase, specific goals have to be set in order to define the concept. The most important factor in this project is undoubtedly the payback time and will be the main objective. This can be broken up in two parts, one being the cost of the device and it's installation, the other being the energy won and therefore the returned money.

A justifiable payback time could be 2 years, there European electronics manufacturers are obliged to provide 2 years of warranty. In other words, return on investment would be guaranteed.

Ideally the device should work for an average family sized system with a low amount of losses (3%-4% a year). However, this might be raising the bar too high. By defining different situations and their goals, the success of the final product can be quantified

Residential use of solar panels

For calculation purposes it is helpful to have some estimated values regarding residential electricity consumption. On the website of Vreg [12] (Flemisch regulator of electricity and gas) the following data can be found:

An average Flemisch family consumes around 3500 kWh each year.

The average unity electricity price for an average consumer in Flanders in 2014 was e0.18/kWh Consequently, the average family spends e630/year Considering a family tries to produce as much energy as it consumes, it is possible to calculate the surface of the PV array needed:

$$\frac{3500kW\,h}{120kW\,h=m^2} \qquad 30m^2$$

According to the Flemisch government the installation cost for 1kWp is on average 1700 euro (6% VAT included). As we know from figure 2.1 1kWp delivers 960kWh/year which means that a system generating 3500kWh would cost roughly 6600 Euro. Given the current electricity price the investment should pay itself back in around 11 years.

ADVANTAGES

This Clean, Noise less

It is a Non-conventional system No fuel is require

Easy maintenance Simple in construction. Pollution free.

Losses in PV systems

As sunlight gets converted in usable electricity there are different losses lowering the systems output power. To quantify the performance of a PV system, a performance ratio [5] is introduced. This ratio represents the final yield (Y_F) divided by the reference Yield (Y_R). In essence it compares the AC output power with the DC power coming out of the module, thus calculating the losses due to the conversion. These losses can be linked to:

panel degradation(h_{deg}) temperature (h_{tem}) soiling (h_{soil})

internal network (h_{net}) inverter (h_{inv}) transformer (h_{tran})

system availability and grid connection network (h_{ppc})

Therefore, the performance ratio (PR) can be expressed as following:

$$Y_F$$

$$R= {}^{=h}{}_{deg}{}^{:h}{}_{tem}{}^{:h}{}_{soil}{}^{:h}{}_{net}{}^{:h}{}_{inv}{}^{:h}{}_{tran}{}^{:h}{}_{ppc}\ Y_R$$

The performance of inverters, transformer,... are increasing due to technological improvements. However soiling (and in a smaller quantity degeneration) can be improved regardless of the technology installed, simply by keeping the glass clean. The next sections will go more into detail of the mechanisms behind soiling and degradation

Validating the models

1 Control

For controlling the robot an Arduino mega 2560 microcontroller board was used. This board is based on the Atmel ATmega2560 microcontroller. With 54 digital input/output pins and 16 analogue ones, the board has enough flexibility for this project. Additionally, the board has 6 interrupt pins (pins 2,3,18,19,20). These are especially important for the operation of the encoders counting the motors rotation.

Every time a pulse arrives from the motors encoder, an interrupt will is triggered, consequently pausing other tasks so each pulse gets registered by the microcontroller. If not connected to an interrupt pin, several counts per revolution of the motor would get lost and therefore the position of the robot would be estimated falsely.

Another reason for taking the Arduino mega is its compatibility with Math works Simulink. In contrary to the Arduino Uno, the Mega allows the user to interact with a Simulink model in real-time. By run the model in so called external mode, all information can be send to and received from the microcontroller in discrete time-steps.

A third advantage of the Arduino is that there is a vast amount of information and examples available on the internet because it is often used for educational purposes.

2 Motors

The brushed DC-motors used in the experiments are 50:1 Metal Gear motor 37Dx54L built by Pololu. Weighing 218 grams each they closely approach the requirements found earlier in the models for a robot with an estimated weight of 1kg.

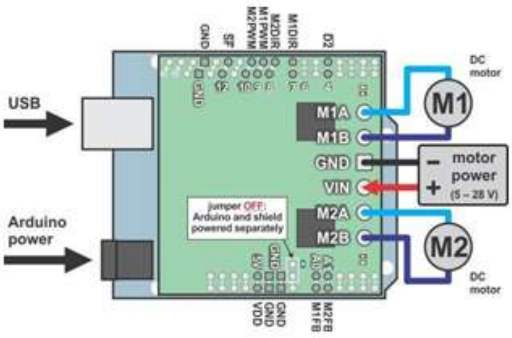
The motors are equipped with quadrature encoders. This two-channel hall effect encoder mounted on the shaft has a

resolution of 64 counts per revolution. Because of the 50:1 ratio of the motor

3 Electronics

To power and control the motors, drivers are required. The Pololu Dual MC33926 Motor Driver Shield [20] was used for this purpose. It combines two drivers on one shield that can be placed on top of the Arduino. This way the electronics are easy to install and all features are compatible with the Arduino environment

The drivers are rated for delivering 3A of continuous current and feedback information about the current drawn by the motors. It also provides built-in protection for over-current and excessive temperature.



4 Mechanical setup

All the parts, (i.e. the Arduino with driver and motors with spools and rope) are then attached to a piece of wood. The wood adds extra weight simulating the weight off the batteries and brush. In total the physical model weighs 1kg.

The spools attached to the motors are 3D printed and have a radius of 4cm. Also a 3D prined wire guide was added to the top of the robot so the wire gets rolled up properly onto the motors.

The ropes were then attached to the corners of a closet, giving it a simulated roof width of 1.1m and a length of 2 meters. The electronics were connected to a voltage source providing the motor driver with 12V. The Arduino was hooked up to the computer using a long USB cable.

As is to be seen in figure 6.2, the motors are not connected at the same height. This is because once the motors are screwed into place the spools couldn't get slid onto the shafts anymore. This difference introduces a slight imbalance making the robot tilt slightly.

III. Results and conclusions

The experiment was repeated three times. At each experiment the limiter (saturation block) in the controller was set to an other maximum voltage. This way the maximum amount of torque to the motors was reduced. The effect of this reduction is that the robot will stall at a different place making it possible to compare the performance of the motors.

Voltage limit	Computer Model	Physical Model
12V	12cm	9cm
4V	30cm	22cm
2.5V	75cm	29cm

Table : Stall distance when pulling robot straight up

It's clear to see that the models act pretty similar at full power. However when the voltage gets reduced and the motors don't have the full amount of torque, the differences become more noticeable. This again leads to believe that the motors are stronger at lower voltages then their virtual counterparts.

This also explains the smaller steady state errors encountered in the physical model. Because the real motors deliver more torque at smaller voltage, the small change in voltage delivered by the controller provides a bigger difference in torque and consequently moves the robot closer to its set point

Reference

[1]. EUROBSERV'ER. Photovoltaic barometer, April 2014.
[2]. A.R. Jha. Solar Cell Technology and Applications. Auerbach, 2010.
[3]. Maxim Tabachnyk, Bruno Ehrler, Simon Gelinas,´ Marcus
[4]. L. Bohm,¨ Brian J. Walker, Kevin P. Musselman, Neil C. Greenham, Richard H. Friend, and Akshay Rao. Resonant energy transfer of triplet excitons from pentacene to pbse nanocrystals. Nature Materials, 2014.
[5]. Wei-Jen Lee Jie Shi, Fellow, IEEE, Yongqian Liu, Yongping Yang, , and Peng Wang. Forecasting power output of photovoltaic systems based on weather classification and support vector machines. EEE transactions on industry application
[6]. Emmanuel Kymakis, Sofoklis Kalykakis, and Thales M. Papazoglou. Performance analysis of a grid connected photovoltaic park on the island of crete. Energy Conversion and Management, 50, 2009.
[7]. Felipe A. Mejia and Jan Kleissl. Soiling losses for solar photovoltaic systems in california. Solar Energy, 95:357– 363, 2013.
[8]. Miguel Garcia, Luis Marroyo, Eduardo Lorenzo, and Miguel Perez3. Soiling and other optical losses in solar- tracking pv plants in navarra. Prog. Photovolt: Res. Appl., 19:211–217, 2011.
[9]. Reinhart Appels, Buvaneshwari Lefevre, Bert Herteleer