Indonesian Journal of Electrical Engineering and Informatics (IJEEI)
Vol. 4, No. 1, March 2016, pp. 54~64
ISSN: 2089-3272, DOI: 10.11591/ijeei.v4i1.187

Two Axes Sun Tracking System for Heliostat in Algeria

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Abstract

In this paper, using Proteus software, sun tracking system with two axes program has developed and simulated for site of GHARDAIA, in the south of ALGERIA. Two direct current motors have used to move heliostat in North–South and East–West axis polar, in order to tracking the sun path.In addition, the distinction between day and night has provided by light dependent resistor (LDR).An algorithm of two axes sun tracking system hab developed and simulated under Proteus software, after DC motor's parameters have verified and simulated under MATLAB software. The results show that: in the first, the development of the heliostat control requires the knowledge of the position of each heliostat relative to the tower to ensure the proper operation of the motors, and the uniformity of the reflected beam to the target.Then the choice of the drive motors is based on the useful power, including the weight of the heliostat, and all efforts affects on operation of motors in different seasons of the year, like the wind.And The position of the heliostat depends of chopper duty cycle.Finally,Conducting a power tower with mobile heliostats requires a techno-economic study on all components (heliostats, tower...) of the plant, for example weather two motors for each heliostat field.

Keywords: *Sun tracking system, Heliostat, DC motor, Proteus software*

1. Introduction

The question of global demand that growing up, specifically for clean energy, climate changes and sustainable development has a large importance in the programs of development in Algeria. This leans the Algerian governments to launch the renewable energies (REs) and energy efficiency program. Solar energy occupies one of the most important places among the various possible alternative energy sources for both urban and rural areas [1], and the strategic choice of this program is motivated by the huge potential of solar energy; in which it is the top source in the Mediterranean basin; more than 2,000,000 km^2 receives yearly a sunshine exposure equivalent to 2500 kWh/m^2 and the mean yearly sunshine duration varies from a low value of 2650 h on the coastal line to 3500 h in the south. This energy is the major focus of the program of which concentrating solar thermal power (CSP) and photovoltaic systems (CPV) constitute an essential part. Solar should achieve more than 37% of national electricity production by 2030 [1, 2].

In general, the power developed in such applications depends fundamentally upon the amount of solar energy captured by the collector, and thus the problem of developing tracking schemes capable of following the trajectory of the sun throughout the course of the day on a year-round basis has received significant coverage in the literature. For example, various schemes have been proposed for optimizing the tilt angle and orientation of solar collectors designed for different geographical latitudes or possible utilization periods [3-4].

A heliostat is a device that automatically tracks the sun as it moves across the sky and constantly reflects the sunlight to a fixed location, typically a thermal collector. For a large scale solar collection system such as a central receiver system, heliostats are essential. In a central receive system; a number of heliostats are employed to reflect sunlight to a single central receiver. Total solar energy is directly proportional to the area of solar intake, the aperture of the system. Thus, the energy is related to the number of heliostats and their reflective area. Working temperature of the receiver, however, related to the system concentration ratio, the ratio of the receiver area to the aperture area. If flat reflective surfaces are used by the heliostats, this concentration ratio is directly proportional to the number of heliostats employed.

Received August 27, 2015; Revised January 6, 2016; Accepted January 18, 2016

To gain a high concentration ratio, a large number of heliostats are required or heliostats with curved reflective surfaces are required.

The solar tracking system should be adjusted so that it is always accurately aimed at the sun. Solar tracking systems with a single axis are less costly and their control is easy to implement, against their effeciency is less than that of solar tracking systems with two axes.

In this paper, using Proteus software, sun tracking system with 2 axes program has developped for site of GHARDAIA, in the south of ALGERIA.O2 DC motors have used to move heliostat in N–S and E–W axis polar, in order to tracking the sun path.the distinction between day and night has provided by light dependent resistor (LDR). An algorithm of two axes sun tracking system hab developed and simulated under Proteus software, after DC motor's parameters have verified and simulated under MATLAB software.

2. Research Method

2.1. Distinction between Day and Night

The distinction between day and night has provided by light dependent resistor (LDR). These passive components exploit the principle of photoconductive. The photoconductivity is a photoelectric effect which is manifested by a decrease in the resistivity of an irradiated material: the release in material of electric charges (electron-hole pairs) under the influence of radiation causes a decrease in resistivity. If a semiconductor crystal is subjected to light radiation, the energy provided by photons can free some electrons used in covalent bonds between the atoms of the crystal. More the luminous flux is intense, more the number of electrons available for conduction is greater, and the resistance is low.

The resistance of the LDR is therefore inversely proportional to the light received, i.e:

$$R = \frac{R_0}{R_p}$$

R_0: Resistor of the cell in the dark

R_p: Resistor determined by the photoresistor effect of the incident flux

$$R_p = aE^{-\gamma}$$

E: Incident flux

A: constant dependent on the material and temperature

γ : coefficient between 0,5 and 1

2.2. Sun Tracking Algorithm

There are different types of heliostat, the best performance from the point of view is the heliostat non- Imaging focusing heliostat, the position of the heliostat varies the geometric coordinates of each site. Mathematical expressions for the solar tracking system are outlined here. The geometry of the heliostat relative to the tower is shown in the following figure:

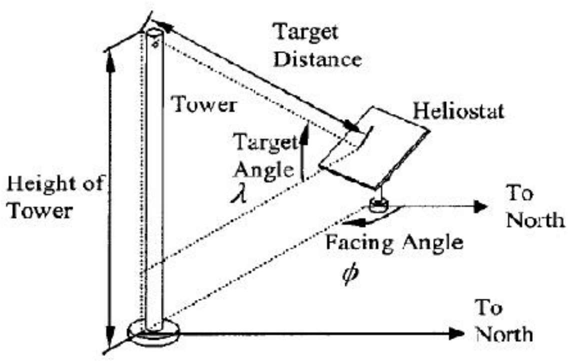


Figure 1. The definitions of geometric parameters used in the comparison of heliostats

The heliostat spin angle ρ_S and the heliostat elevation angle θ_S are as follows:

$$\rho_s = \arcsin\left(\frac{-\cos\delta\cos w\sin\varphi\sin\emptyset+\cos\delta\sin w\cos\varphi+\sin\delta\sin\varphi\sin\emptyset}{\cos(\frac{\pi}{2}-2\theta)}\right) \quad (1)$$

$$\theta_s = \theta \quad (2)$$

θ is the incidence angle:

$$\theta = 0.5\, arc\cos(-\sin\gamma\sin\alpha + cos\gamma\sin\varphi\, cos\alpha\sin A + cos\gamma\, cos\varphi\, cos\alpha\cos A) \quad (3)$$

α is the solar altitude angle:

$$\alpha = arc\sin(\sin\delta\sin\emptyset + cos\delta\cos w\cos\emptyset) \quad (4)$$

A is the solar azimuth angle:

$$A = arc\cos\left(\frac{\sin\delta\, cos\emptyset - \cos\delta\cos w\cos\emptyset}{\cos\alpha}\right) \quad (5)$$

λis the target angle; φis the facing angle; δ is the declination angle; Φ is the latitude; and w is the hour angle.

2.3. Modeling of DC Motor

Changes in technology led to the use of machines that require precise and variable speeds drive to driving handling equipment for example. The DC machines are commonly used in self systems and applications : , drills etc ...-.
The motor behaves as a resistor in series with a voltage generator;
What characterizes the motor/

- Its rotation speed
- Its supply voltage
- the maximum current that can flow in the motor
- its Torque

$$E = K\Phi\Omega \quad (6)$$

$$T_{em} = K\Phi I \quad (7)$$

$$U = E + RI \quad (8)$$

In the above:

$$K = (p/a)N/2® \quad (9)$$

Φ: magnetic flux
I: the current consumed by the motor
T_{em}: electromagnetic torque

$$U_m = R_m \cdot I_m + L_m \cdot \frac{dI_m}{dt} + E$$
$$E = K_E \cdot \Omega \quad (10)$$

$$J \cdot \frac{d\Omega}{dt} = C_m - C_f - C_u \quad (11)$$

Neglecting friction, the transfer function of the motor is:

$$T(p) = \frac{\Omega(p)}{U_m(p)} = \frac{1}{\frac{RJ}{K} p + K} \qquad (12)$$

To improve accuracy, decrease stability and slow down the system, we added to our block a PI regulator which provides these functions, and then the transfer function becomes:

$$T(p) = \frac{\frac{k_p}{k_i} p + 1}{\frac{p^2}{\left(\frac{k_i.k_1}{2_m}\right)} + \frac{(1 + k_p.k_1)}{k_i.k_1}.p + 1}$$

We have seen that the speed of DC motor with separate excitation is proportional to the supply voltage which is independent of the load; it is useful in controlling the engine speed by varying the average voltage across the armature. For this, the chopper is the right power converter for this command.

A chopper is a static converter for powering a load, under medium voltage adjustable value, with a very good yield.

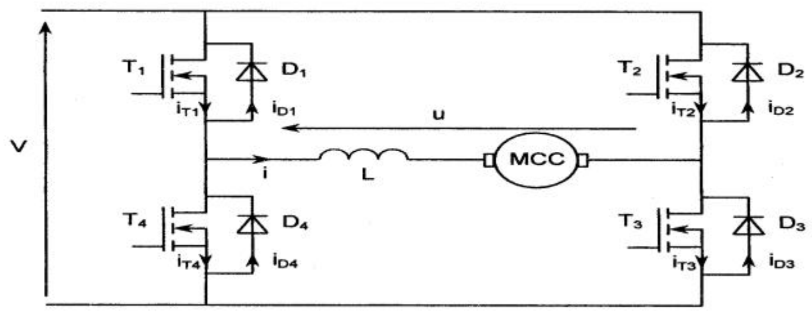


Figure 2. The speed control of a DC motor by a chopper

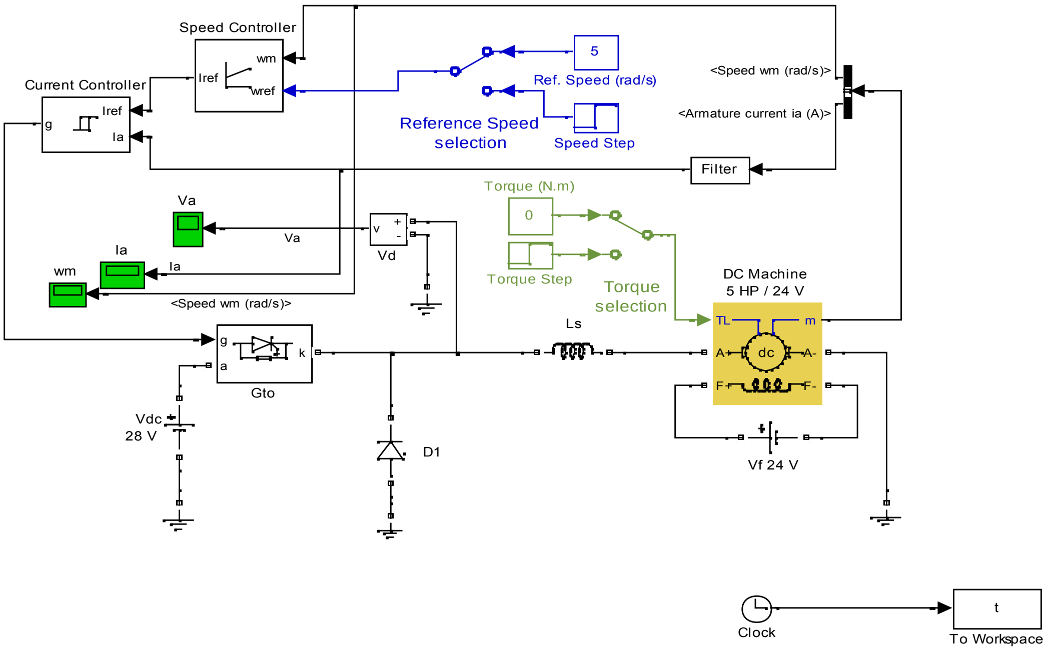


Figure 3. Simulation of DC motor under MATLAB sofyware

2.4. Driving Circuit with Microcontroller

Microcontrollers are now established in most consumer and professional applications, there are several families. American society Microchip Technology has developed in the 90 CMOS microcontroller: PIC (Peripheral Interface Contrôler). This component still used today, is a compromise between ease of use, speed and cost.

2.4.1. The Choice of Microcontroller

The choice of PIC is directly related to the intended application.

- It is necessary in a first time to determine the number of Inputs/ Outputs required for the application, the number of I / O gives us a first family of PIC.
- Then determine if the application requires an Analog / Digital converter which will focus towards the choice of a family of PIC.
- Timeliness is important, must check-BOOK DATA to verify compatibility between the maximum speed of selected PIC and max speed required for installation.
- The size of the internal RAM and the presence or absence of an EEPROM for storing data is also important for the desired application.
- The length of the application program determines the size of the program memory of PIC sought.

In our study, we used PIC16F876, which number 16 means it is part of the "MID-RANGE" family, the letter F indicates that the type of PIC program memory is "Flash".

The last three digits identify precisely the PIC, here is a PIC of the type 876.

The 16F876 have more very powerful instructions, so a program to develop small, and simple programming. 16F876 has more ROM compared to other microcontroller, which is needed to develop longer programs, thus the presence of an analog / digital converter for measuring critical value of the photoresistor.

2.4.2. Thermal Relay (H bridge)

When one wants to control the direction of rotation of a motor (DC or stepper) it is often necessary to reverse the polarity. Moreover, it is generally preferable to be able to vary the speed of the motor. The solution is to use the H-bridge

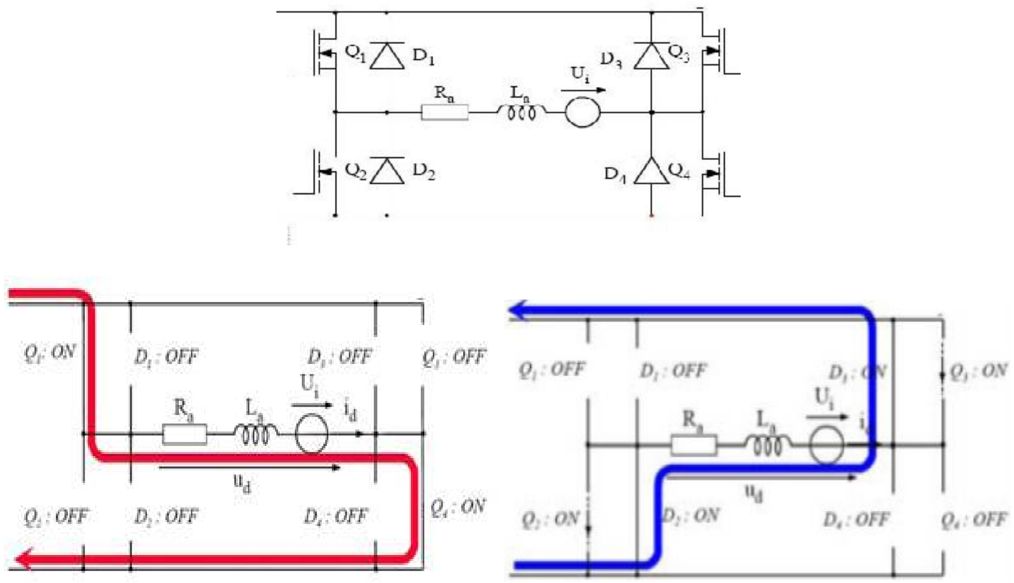


Figure 4. H Bridge

Table 1. Principle of H Bridge

IN1	IN2	STATE
0	0	OFF
0	1	DIRECTION 1
1	0	DIRECTION 2
1	1	OFF

2.4.3. ULN2003 Circuit

The ULN is a component in which to order the thermal relays, it has two transistors, two diodes and two resistors. The ULN is able to sell a maximum current of 500mA per transistor and supports a maximum voltage of 50V.Thus you can connect most relays directly without any problem.

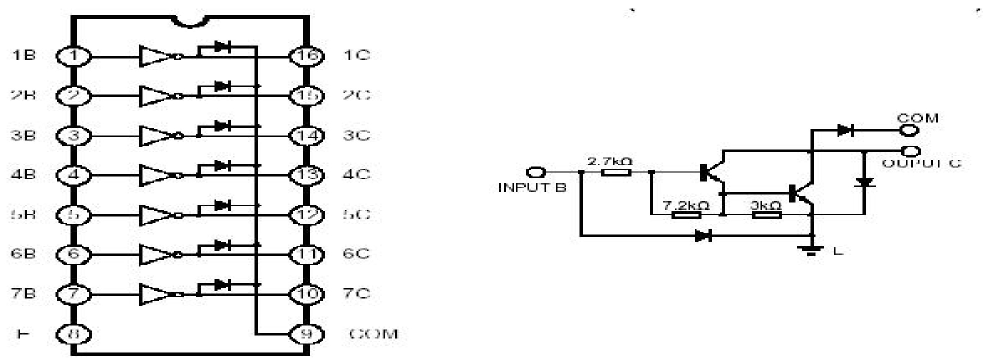
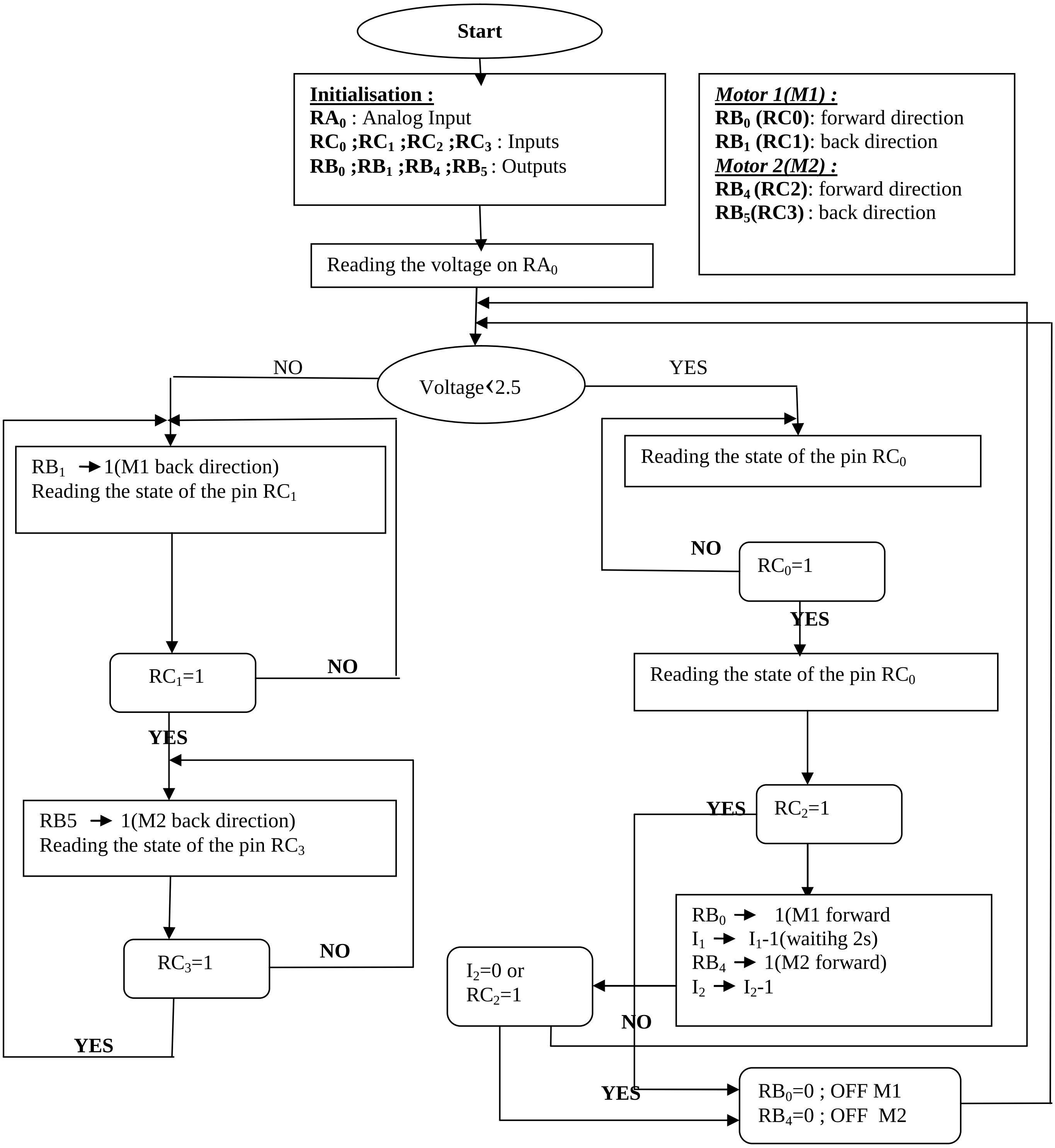


Figure 5. Internal structure of ULN2003

2.5. The Control Flow of a Mobile Heliostat



2.6. Simulation of the Card by the PROTEUS Software

Figure 6 represents card of control of two motors under PROTEUS software, using parameters of site.

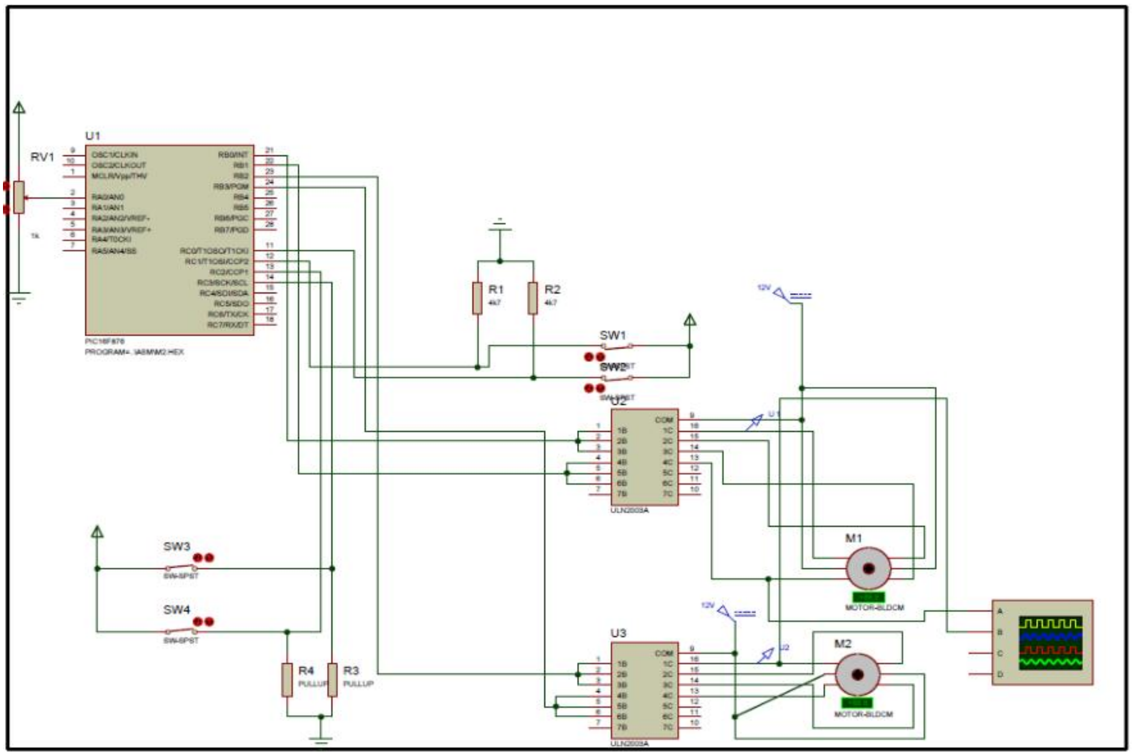


Figure 6. Card of control of motors under PROTEUS software

3. Results and Analysis

The data used in this work are related to the site of Ghardaia; in table 2 are shown the geographical features of this website.

site	Latitude (°)	Longitude (°)	Altitude (m)
Ghardaïa	32.4	3.80E	468.4

3.1. Simulation under MATLAB software

We simulated our motor under MATLAB software, the reference speed is 5 rad / s at the outlet of the motor or gearbox input from the day; the supply voltage is 24 V, with a ratio of 20%.

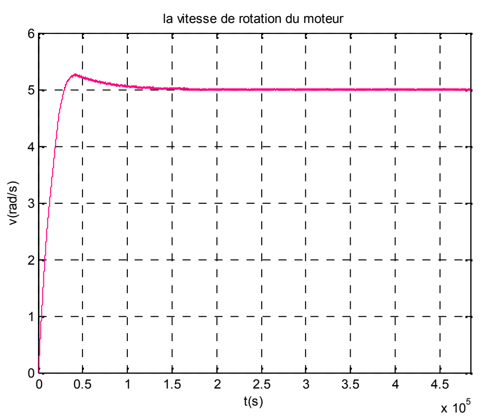


Figure 7. The Rotational Speed of motor

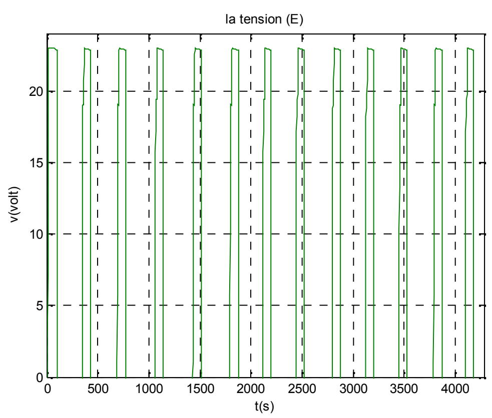


Figure 8. The voltage applied to the motor

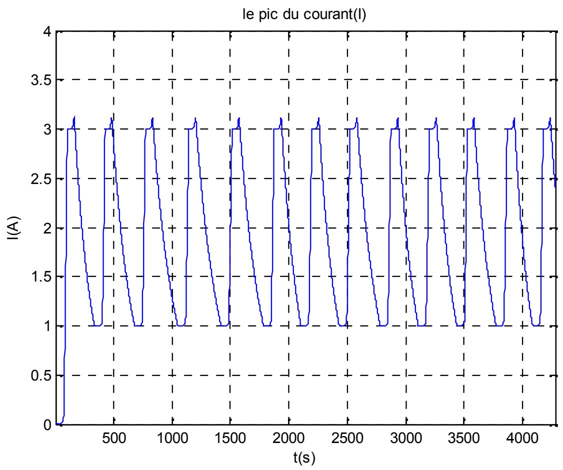


Figure 9. The excitation current transient

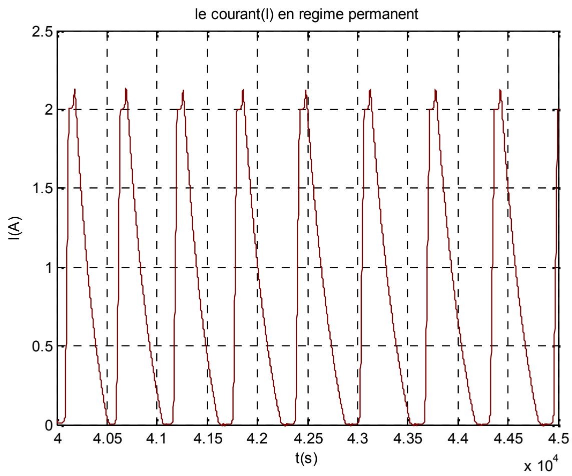


Figure 10. The excitation current steady

3.2. Simulation under PROTEUS Software

We simulated motor, but this time in PROTEUS under the same previous conditions.

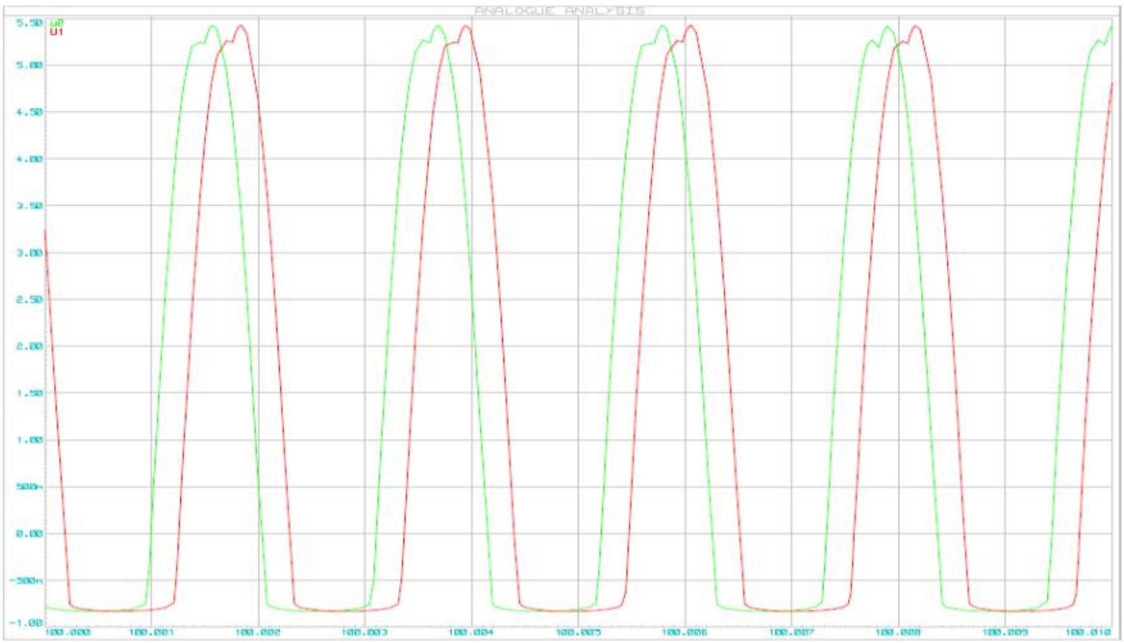


Figure 11. The supply voltage of two motors

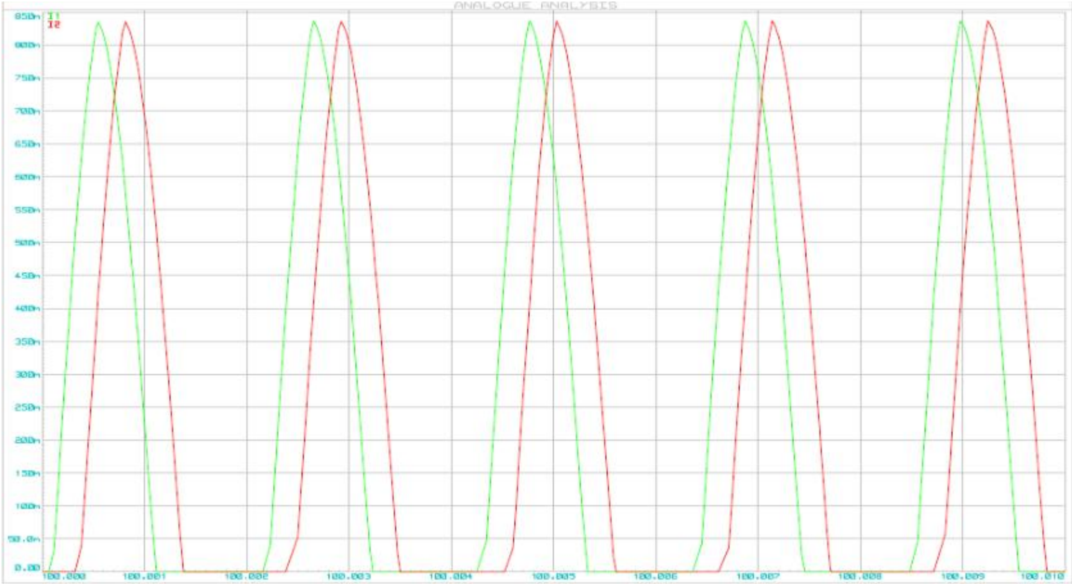


Figure 12. Current excitation steady of both motors

We simulated the different parameters of the DC motor under two software MATLAB and PROTEUS then noted the following observations:

1- The rotational speed of the motor follows the reference speed (5 rad / sec), with a transitional period of 1s and speeding to 5.1 rad / s.
2- The supply voltage is chopped with a duty cycle α = 20% ie the time of the low state is greater than the time of the high state.
3- Peak transient current varies between a maximum value=3A and a minimum value = 1A in a period of 1s, then stabilizes between I_{max} =2A, and I_{min} = 0A. Under PROTEUS the maximum current is 1A.
4- Both motors at night just to the initial state directly with a constant and uniform speed and then remain at rest until the detection of day with the photoreceptor.

4. Conclusion

The work realized, is focused on controlling a heliostat of solar tower power plant reflect sunlight to a fixed target plane using a microcontroller PIC 16F876. The purpose of this project lies in developing a program to ensure a concentration of solar radiation in the receiver.

The results show that the development of the heliostat control requires the knowledge of the position of each heliostat relative to the tower to ensure the proper operation of the motors, and the uniformity of the reflected beam to the target, and the knowledge of chopper duty cycle value. In addition, the choice of the drive motors is based on the useful power, including the weight of the heliostat, and all efforts affects on operation of motors in different seasons of the year, like the wind, then, To ensure accurate position of a heliostat, order motors with voltage pulses, why the DC motor with separate excitation is the one which checks this function, because its speed is adjustable by the supply voltage.

Finally, conducting a power tower with mobile heliostats requires a techno-economic study on all components (heliostats, tower...) of the plant, for example weather two motors for each heliostat field.

References

[1] TE Boukelia, MS Mecibah. *Solid waste as renewable source of energy: current and future possibility in Algeria*. *Int. J. Energy Env. Eng*. 2012; 3(17).

[2] TE Boukelia, MS Mecibah. *Parabolic trough solar thermal power plant: Potential, and projects development in Algeria*. *Rene. Sustain. Energy. Rev.* 2013; 21: 288–97.

[3] HJ Mohd Yakup MA, AQ. *Optimum tilt angle and orientation for solar collector in Brunei Darrussalam*, *Ren Energy*. 2001; 24: 223-234.
[4] Bari S. Optimum slope angle and orientation of solar collectors for differents periods of possible utilization. *Energy Conve* Manag. 2000; 41: 855-860.
[5] Z Yinhai *and al. A Novel SVPWM Modulation Scheme*. *in Applied Power Electronics Conference and Exposition, 2009. APEC 2009.* Twenty-Fourth Annual IEEE. 2009: 128-131.