RASPBERRY PI FOR SOLAR TRACKING

LESSON PLAN 2

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1.1 General information

1.1.1 Short description

SOLAR TRACKING (Sun Position, Sun Tracking, Sun Following)

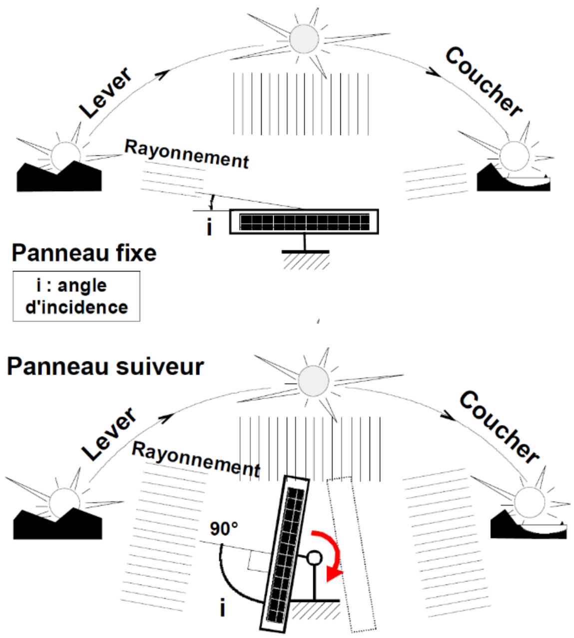
Solar tracking systems are designed and developed to increase the amount of solar radiation received by photovoltaic devices. This process is achieved by maintaining the optimal angle of the solar panel to produce the best power output (Bernardi et al. 2012; Shafie et al. 2011). Solar tracking systems have been used in many places around the world. Many solar tracking systems have been built and designed to achieve the optimal amount of solar energy, and many models have been proposed to enhance the benefits of using solar panels. Several studies have focused on the design and implementation of solar tracking systems for different geographic regions. The figure above shows the difference between using a fixed angle photovoltaic solar system and a simple tracking system (Assaf 2014; Deb and Roy 2012; Hines and Gross 2008; Huang et al. 2009; Juang and Radharamanan 2014; Lakeou et al. 2006; AL-Rousan et al. 2012; Rahman et al. 2013; Schumacher 2000; Tudorache and Kreindler 2010).

Among all the technologies that can be mobilized to meet this challenge, two families of solutions compete:

- Scheduled trackers (requiring calculations to predict the solar trajectory);
- Sensor trackers (requiring real-time detection of the solar position).
- The functioning of the 1st family of followers who (interests us) requires:
- Program and trajectory calculation
- Computer data;
- Connection with a computer consuming little energy to collect data;

The second family includes all the components of the 1st but requires a potentiometer angle panel and a shading system containing photovoltaic sensors.

In this study, we present the implementation of a two-axis (azimuth and height of the sun) solar tracking system controlled by an Arduino board with measurements of current intensities and voltages and compare the powers with those of a fixed photovoltaic panel.



1.1.2 Learning objectives

The main learning objectives of this lesson plan are:

- concept and content understanding of Electronic kits, to inspire students to invent with electronics and coding
- designing and performing an experiment or scientific investigation with collection of data, analysis and presentation of results, providing tools to solve the technology challenges of tomorrow
- familiarizing with circuits and programs to interact with GPIO pins of Raspberry Pi, to inspire and engage students with coding, design-thinking, and engineering
- understanding basic structures of programming, using Learning electronics

1.1.3 Links to curriculum

The domains, subdomains, subjects/topics that this lesson plan can be linked to are:

- Physics: motion, oscillation, waves, types of waves, characteristics of waves, propagation of waves, sound, speed of sound waves, spectrum of sound waves
- Science (Physics/Chemistry/Biology/Geology): scientific method, investigation, experimentation, analysis and interpretation of results
- Computer Science/Informatics: processing unit and peripherals, interfaces, programming language and main structures, coding
- Technology: electronics, open-source hardware and software, sensors, digital signal, circuits, single board computers

Maths/Statistics: spreadsheets and basic statistics

1.1.4 Materials required

Cylinder (number 2)

The cylinder is the motor which will produce a translation which we will then transform into rotation thanks to certain mechanical elements so it would be interesting to know how this motor works.

The operating principle of the DC motor can be easily explained. A DC motor consists of two parts: a fixed part which generates a magnetic field (the stator) and a rotating part (the rotor). A DC motor is made up of two electrical parts: the stator and the rotor. When the engine is powered, a magnetic interaction is created which sets the engine in motion. When you reverse the direction of the voltage that powers the motor, it turns in the opposite direction.

The stator of a DC motor is the fixed part of the motor (static = which does not move). The stator is also called the inductor or the excitation: one makes pass a current in the winding of the stator and it is it which creates (which induces) a magnetic field. It therefore sets the scene for the rotor which thus finds itself immersed in this magnetic field. The stator creates a magnetic field called the induction field.

The rotor is the rotating part of the motor. It is he who turns. It consists of the induced winding. This coil must be powered to transform it into an electromagnet which will interact with the stator. If the rotor were not powered, it would not be subject to any force and would not rotate. A special friction system is used to power the rotor: brushes (or coals mounted on springs) rub on the rotating contacts: the collector.

Transformer

In most power supplies connected to the mains, a transformer is present. Its role is to provide electrical insulation while transferring power. For the majority of assemblies, it lowers the 230V mains voltage to a value compatible with the circuits (12V, 24V, etc.).

The transformer consists of a closed ferromagnetic core made with iron or ferrite. The winding which serves as input is called primary, the other winding (output) is called secondary. The primary is powered by an AC voltage (mains in most cases), at the secondary then appears an alternating voltage (induced electromotive force).

If a load (resistor which creates an output current) is connected to the secondary, a current called by the primary appears which is proportional to the secondary current. Electrical power is thus transferred from primary to secondary, while preserving the insulation. The transformer is thus reversible.

Our transformer has an input of 230V in alternating current and an output of 50V in direct current.

Relay (5V, until 10A, number 8)

A relay is a switch which is controlled with a low power DC voltage. The "switch" part is used to control high power mains loads.

An electronic relay has a winding as a control device. The voltage applied to this coil will create a current, this current producing an electromagnetic field at the end of the coil (it is neither more nor less than an electromagnet). This magnetic field will be able to move a metallic mechanical element mounted on a movable axis, which will then move mechanical contacts. In our case, we will use 5V relays capable of driving up to 10A and the coil will be excited thanks to our Arduino board.

Photovoltaic sensors (number 4)

The photovoltaic sensors are fixed on the same plane as the photovoltaic panel, they measure the radiation and send the information to Arduino (because they are connected)

Bridge H (electrical structure resulting for each motor)

The H-bridge is an electronic structure used to control the polarity across a dipole. It is made up of four switching elements generally arranged schematically in an H shape, hence the name. The switches can be relays, transistors, or other switching elements depending on the intended application.

The H-bridge makes it possible to perform 2 functions which are to reverse the direction of rotation of the motor by reversing the current at the terminals of the motor and the variation of the speed of the motor by modulating the voltage at the terminals of the motor.

In addition, the H-bridge allows magnetic braking if it is able to dissipate the power generated. This operation is carried out by actuating either the two upper or lower switches at the same time, which short-circuits the motor terminals, and consequently causes it to brake. Even better, it is possible with little electronics and an improved controller to perform regenerative braking. In the case of battery power, energy is returned to the batteries rather than dissipated in the bridge switches.

ARDUINO (Mega 2560)

An Arduino module is generally built around a microcontroller and complementary components which facilitate programming and interfacing with other circuits. Each module has at least one 5 V linear regulator and one 16 MHz crystal oscillator.

The card is programmable via the software of the same name in C language and available free of charge. The program can be downloaded with just one click!

The microcontroller is preprogramed with a boot loader so that a dedicated programmer is not necessary. In other words, he is ready to re-execute the last program used the last time he connected to a computer. The Arduino uses most of the microcontroller's inputs / outputs for interfacing with other circuits.

The Arduino Mega 2560 board contains everything necessary for the operation of the microcontroller

Arduino components

Several components can be connected and implemented on Arduino such as the current and current sensors necessary for taking measurements. These components are easily programmable and integrated into systems, but are not essential for solar tracking. They are used for comparison purposes. Add cables and resistances.

Solar panel (number 2)

Photovoltaic cells are made of one or more semiconductor materials and are used to directly convert solar energy into electrical energy. To cause this effect, called the photoelectric effect, the semiconductor material must be "doped". Due to the addition of chemical elements, two layers are obtained, a conductive layer p with an excess of positive charge carriers and a conductive layer n with an excess of negative charge carriers. This imbalance results in the formation of an internal electric field at the junction, which causes charge separation upon exposure to light. The charge carriers thus freed can be evacuated by metal contacts and used directly as direct current (DC), an intercalated inverter transforms it at alternating cost which allows injection into the grid.

1.1.5 Duration

The duration of this lesson plan is estimated to be about four classroom hours.

1.2 Lesson plan

The solar tracking of the photovoltaic panel will be done by a jack with a DC motor. A transformer will manage the passage from alternating current to direct current. To do this automatically, we will place the engine in an H bridge using relays. An Arduino board will take care of energizing the relay coils to control the motor. A program will calculate the azimuth and height of the sun and monitor the sun.

A measurement side will be placed in order to take the powers generated from the follower panel and another fixed in order to compare the experimental results. This measurement will be made using adaptable and programmable current and voltage sensors with the Arduino board. Other elements are required such as cables, resistors and bulbs adapted to the power of the used photovoltaic panels.

Electrical diagram of the follower; established from Proteus (ISIS) free edition by Labcenter Electronics.

We see it better through the diagram. If Relays 1 and 3 are energized at the same time without energizing the other two, the motor will start in one direction. If you do the opposite, the motor will run in the opposite direction.

Steps

Assembly:

Provide the diagrams and request assembly: connect the relays (Switches, RLi) to the motor. If they receive 5V it lets the current and the motor starts.

Connect ammeters and voltmeters to the Arduino board for measurement

Programming:

Write the program: Aim: all photovoltaic sensors will receive the same light intensity.

The program will compare the intensities of the north/south sensors and excites (gives a voltage of 5V) to the two relays responsible for the movement of motor 1 to scan over the height until the two intensities become equal.

The program compares the intensities of the east/west sensors and excites the two relays responsible for the movement of the motor to make the azimuth scan until the two intensities become equal.

Repeat the comparison and movement operations if necessary, after a Delta t time (loop)

Arrived at a certain time (hour limit of sunset calculable in Arduino via astronomical calculations) excite the relays to position full east and minimum height to prepare for the next day and repeat the time loop

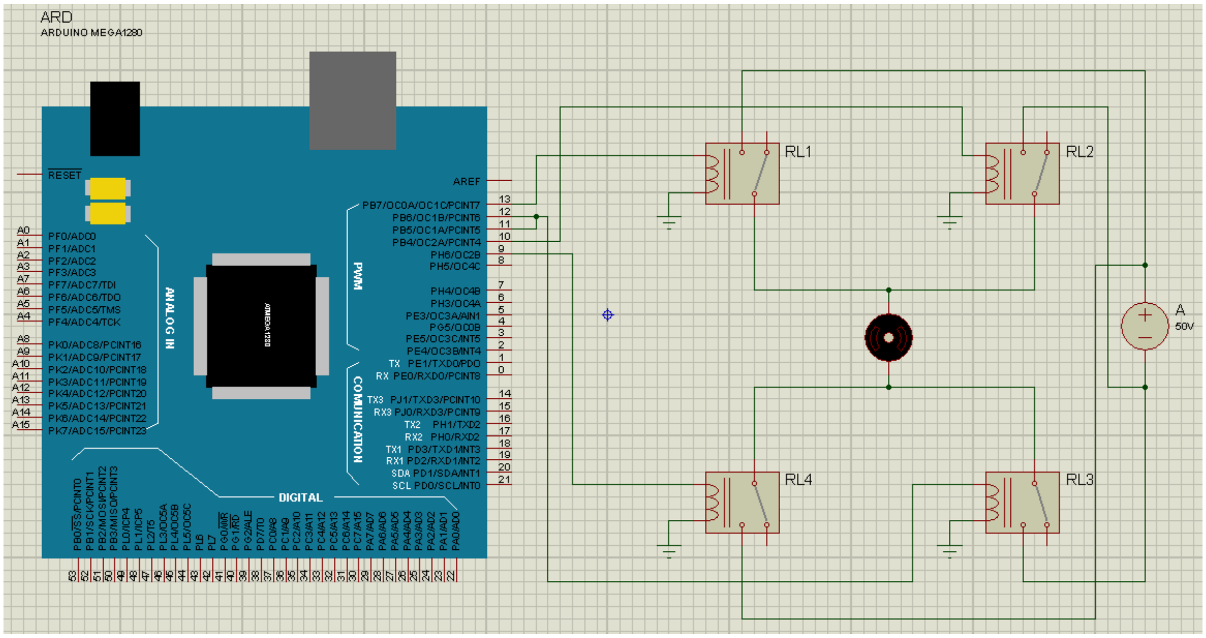
Tests:

With a lamp by changing the angle

Example: open relay 1 and 3 to scan (east-west movement along the azimuth) until the 2 photovoltaic sensors will receive the same light intensity. The diagram below is according to the azimuth.

Repeat the same procedure for the sweep according to the height.

Comparison between fixed and mobile panel: compare the power curves



1.3 References or Resources

Assaf EM. Design and implementation of a two-axis solar tracking system using plc techniques by an inexpensive method. Int J Acad Sci Res 2014;2(3):54–65.

Bernardi M, et al. Solar energy generation in three dimensions. Energy Environ Sci 2012;5(5):6880–4.

Deb G, Roy AB. Use of solar tracking system for extracting solar energy. Int J Comput Electr Eng 2012;4(1):42.

Hines BE and Gross W. Tracking solar collector with non-uniform solar cells and empirical tracking system including solar angle information. 2008, Google Patents.

Huang Y, et al. The design and implementation of a solar tracking generating power system. Eng Lett 2009;17(4):1–5.

Juang J-N, and Radharamanan R. Design of a solar tracking system for renewable energy. In: Proceedings of Zone 1 Conference of the American Society for Engineering Education (ASEE Zone 1); 2014. 2014. IEEE.

Lakeou S, et al. Design of a low-cost digital controller for a solar tracking photovoltaic (PV) module and wind turbine combination system. In: Proceedings of 21st European photovoltaic solar energy conference. 2006.

Gerro Prinsloo, Robert Dobson, SOLAR TRACKING, 2015 Book Edition, ISBN: 978-0-620-61576-1. Available online

Rahman S, et al. Design & implementation of a dual axis solar tracking system. Am Acad Scholar Research J 2013;5(1):47.

AL-Rousan Nadia, AL-Rousan Mohammad, Shareiah Adnan, Hazem AL-Najjar. Choosing the efficient tracking method for real time tracking system in Jordan and its neighbours to get maximum gained power based on experimental data. In: Proceedings of international conference on renewable energy research and applications (ICRERA); 2012. IEEE.

Schumacher JO, Numerical simulation of silicon solar cells with novel cell structures. 2000.

Shafie S, et al. Current energy usage and sustainable energy in Malaysia: a review. Renew Sustain Energy Rev 2011;15(9):4370–7.

Tudorache T, Kreindler L. Design of a solar tracker system for PV power plants. Acta Polytechnica Hungarica 2010;7(1):23–39.