

Sun Tracking System for PV Panels

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ABSTRACT: Photovoltaic (PV) panels directly convert the solar energy to electrical energy. This paper discusses the design and implementation of computer-controlled sun monitoring device installed in a photovoltaic panel designed in order to boost energy output from the solar photovoltaic (PV) panels. The Sun Tracking device is driven by two permanent DC motors which provides motion to PV panels along its axis. The control of the dual axis monitoring device control isn't a simple job because of the non-linear dynamics and lack of perfect model availability parameters. Hence, a PC based Fuzzy logic control dependent on the knowledge of the system behavior and is design in order to achieve control objective. The implementation of such a controlling system is realized by making an interfacing card comprising of sensor data acquisition, motor driving circuits, and some serial communication with a system. A set of laboratory based demonstration shows the capabilities of the system to track the sun effectively.

KEYWORDS: Sun-tracking, photovoltaic module, solar position algorithm, UART, Control system.

INTRODUCTION

Conventional fossil fuels such as petroleum, natural gas, and coal, which today meet much of the world's energy demand, are rapidly depleting. In addition, their combustion products cause global problems such as greenhouse effects and pollution; which pose great threats to our atmosphere and ultimately to our planet's entire existence. Consequently, renewable energy sources, alternative energies and the efficient use of fossil fuels have become far more important today than ever in history [1].

Since it is an abundant and environmentally friendly fuel, solar energy is one of the most important clean and sustainable sources of energy. Solar energy is used in thermal applications and in producing electricity. Photovoltaic (PV) panels are one of the methods used to generate electricity from solar energy. The PV panels transform the solar energy directly into electricity. The photovoltaic cycle passively generates electricity and is completely self-contained; because there are no moving parts. They also have very low running and maintenance costs; and their modular construction is a real solution for rural areas and settlements where power grids do not exist [2].

The use of photovoltaic (PV) panels [3] is thus one of the promising choices in the generation and utilization of solar electricity systems. PV panels are more efficient, feasible and achievable options for electricity generation due to lower prices of photovoltaic panels and rising costs of traditional fossil fuels. PV systems consisting of photovoltaic panels provide an economic solution especially for rural areas where grid is not reached. PV devices, on the other hand, are environmentally friendly energy-sources because they do not cause any environmental problems. Moreover, they can be configured for any power range needed. Given these benefits, many commercial photovoltaic panels made from semi-conductor materials cannot be controlled with high efficiency because a part of the obtained sunlight is reflected from the photovoltaic panel causing their efficiency to decrease. The semi-conductor materials often absorb some portion of sunlight, and then the rest can be transformed into electricity. The transformed electrical energy constitutes around 20 percent of the solar energy that enters the solar cells. The amount of electrical energy that PV panels convert depends on incident solar radiation, cell temperature, and angle of incidence of the sun [4].

Two major factors inhibiting future widespread use of PV panels: their efficiencies and costs. On the other hand, certain problems are removed by technical advances. The first solar cell's output was around 4 percent, with a price of 750 US\$ for each Watt. Nowadays, however, the efficiencies of photovoltaic panels have risen to about 15 percent, while the cost for each watt has risen to \$6–7. This cost reduction and performance increase easily show that PV systems will be cheaper and more effective in the future.

Sun monitoring systems can be used to increase energy output as they keep the photovoltaic panels perpendicular to the solar radiation coming in. As the location of the sun shifts during the day, the sun tracking systems modify the photovoltaic panels to allow them to always be precisely pointed towards the sun. Some sun tracking system classifications are based on the ability to shift and the control units. Sun tracking systems are designed to track the sun on a single axis (depending on the azimuth angle) or track the sun on both axes (depending on the azimuth and solar angles of altitude) [5].

Single axis tracking systems are significantly cheaper and simpler to install but their effectiveness is lower than that of two-axis sun tracking systems. Regarding control devices, the main types of sun tracking systems are divided into two: passive (fluid motion, bimetallic lines, controlled viscous damper, etc.) and active (microprocessor, electro-optical, controlled photo sensor, etc.). No electronic control or motor is expected of the passive sun tracking systems. On the other hand, passive sun monitoring systems by Zomeworks, for example, lose sight of the sun as it tries to reposition itself. They start moving in the wrong direction every day because their moves are given by heating each side of the sun tracker. Such systems also do not refer to the climate conditions at low temperatures.

Generally Stepper motors are used in active tracking systems. However, two stepper motors (one for each axis) are required to control panel on x and y axis. Cost of installation, control and service maintenance of both stepper motors will trigger service/maintenance costs, system size, complex control software, and more equipment problems. High clustered PV arrays are predicted to be available commercially in the near future with some technological advancements and fair prices. However, the potential use of these solar photovoltaic arrays for low-scale installations will bring a new form of problem related to the need for high-precision solar monitoring. The high concentration PV arrays need greater precision in solar tracking than traditional photovoltaic arrays; thus, a relatively low pointing error for installing such systems will have to be achieved. Operation and deployment of large-scale plants should also be optimized [6].

MECHANICAL SETUP

The main part of the setup is a circular plate which mounts the solar panel and the optical sensors on top of it. The plate rotates around the horizontal axis which helps the sun to track East-West. This strength is placed on a frame that rotates around the azimuth axis allowing the sun to track Uie North- South. Two dc motors are used to bring the photovoltaic panel in these two directions to its desired direction.

FUZZY LOGIC CONTROL ALGORITHM

A fuzzy logic control algorithm for motion control systems communicates system behavioral information in linguistic control rules and translates them into crisp control law. Fuzzy logic control techniques may therefore be used to control complex, nonlinear systems with unknown or undefined dynamics. The sun tracking device considered in this paper has unknown model and parameters which are uncertain. The device dynamics can be represented roughly by four linearized differential equations, two of which describe each motor's electric circuit and the other equations describe the mechanical equation in the east-west and north-south directions. The moment of the moving pieces being inertia, friction coefficient and backlash is unknown. The machine behavior is well understood, however, and the motor voltages (control signal) can be correlated with the sensor voltages (input signal) in tennis of language if-then rules.

Therefore, a fuzzy logic-based control algorithm using system behavior information is built to prevent system modeling and parameter recognition. In order to monitor the solar rays, two fuzzy controllers are proposed to generate proper motor voltage for each engine. A typical FLC comprises three basic elements, a fuzzification signal for input, a fuzzy engine and a defuzzification signal for output. Fig.4 demonstrates the basic structure of a fuzzy logic controller (FLC). The continuous input signal is transformed into linguistic fluctuating variables in the fuzzification block.

Fuzzification

The controller input variables are described as:

$$e(SN) = e1 - e2$$

$$e(EW) = e3 - e4$$

Where $e(SN)$ and $e(EW)$ are voltage errors respectively in the South-North and East-West directions and $c_i, \ll 2$. Sensor output voltages are c_i and e . Such variables are transformed using correct scaling factors, and then translated into linguistic variables that can be interpreted as fuzzy sets labels. For the scaled inputs, seven linguistic variables are used, namely: positive large (PB), positive medium (PM), positive small (PS), zero (Z), and negative small (NS), negative medium (NM), and negative large (NB). A fuzzy set is defined by assigning the membership values degree to each entity in the discourse universe. The choice of membership role depends largely on the success of the designer. In this paper, membership functions in triangular form, as shown in figure 2, are working.

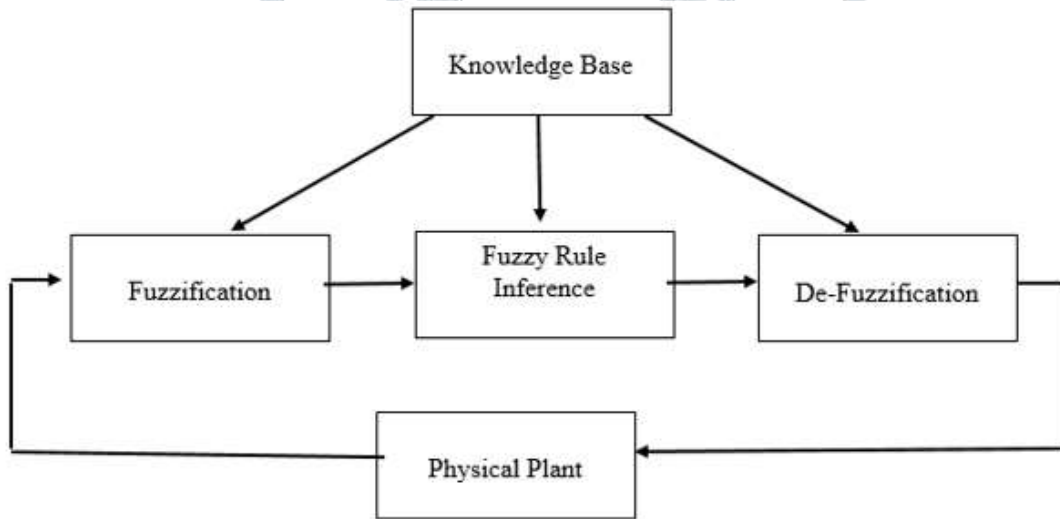


Figure 1: Structure Of A Typical Fuzzy-Logic Controller.

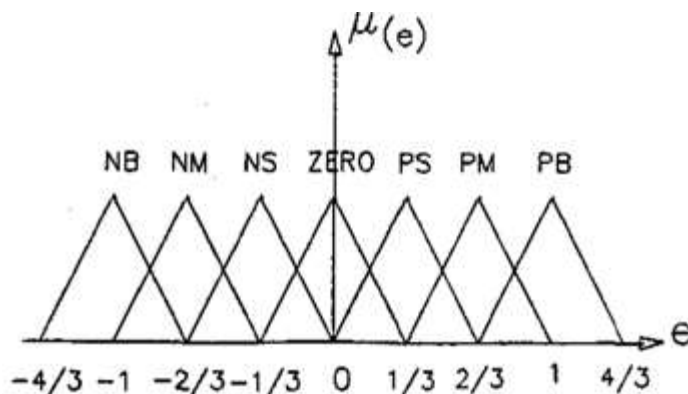


Figure 2: Membership Function Of Input Variable.

Linguistic rules

The fuzzy control rules are built on the basis of intuition and experience gained regarding the sun tracker's actions rather than the availability of its mathematical model. The following basic structure of a general linguistic rule is chosen: IF $e(k)$ is A Then $u(k)$ is B where $e(k)$ is the mismatch in the sensor outputs defined in (1) and $u(k)$ is the control input (which is the fuzzy controller's output) and A and B are the fuzzy subsets defined in the $e(k)$ and $u(k)$ discourse universes respectively. The control inputs are the South-North motor voltage v_s , and the East West located motor voltage v_e , respectively. For both the motors linguistic variables and membership functions are

Input (e_{xy})	Output (v_i)
NB	NB
NM	NM
NS	NS
Z	Z
PS	PS
PM	PM
PB	PB

Table 1: Fuzzy Rules For The Motor Voltage.

Where $XY = \begin{cases} N & \text{for } i = 1 \\ E & \text{for } i = 2 \end{cases}$

The rules given above are formulated on the basis of the following observations:

- 1- If the discrepancy in the exy voltage of the sensor is zero, both engines should be in a position to rest.
- 2- If the inconsistency in the exy voltage of the sensor is positive, positive v_i should be produced to drive the engine in order to cancel the inconsistency.
- 3- If the exy voltage difference is negative, negative v_i will be used.

De-fuzzification

A defuzzification block may basically be viewed as a mapping from a space of fuzzy control actions defined over a discourse output universe into a space of crisp control actions. The aim of the defuzzification block is to produce a crisp control action which best represents the possibility of distinguishing from an action of inferred fuzzy control. Many defuzzification techniques such as max criterion, mean of max, winner takes all and center of gravity methods are available in the literature, the commonly used defuzzification approach is the center of gravity (COG) which is adopted in this paper.

THE CONTROL HARDWARE

Control circuit block diagram is shown in Figure 3. The circuit consists of three major components, namely data collection, motor drive circuits, and serial communication with the PC. The section regarding data acquisition consists of:

1. A photo-diode comprising four different matched sensing components grouped in a quadrant. The output voltage of each quadrant is available separately to achieve high precision location sensing when there is an equivalent shading degree;
2. Using the signal conditioning system, as the incident sunlight reaches the sensors, the photon flux induces the currents to pass through the sensors.
3. Some analog to digital converter receives the sensor readings corresponding voltage levels. Using the successive approximation technique, those signals are sequentially converted to an 8-bit binary word.

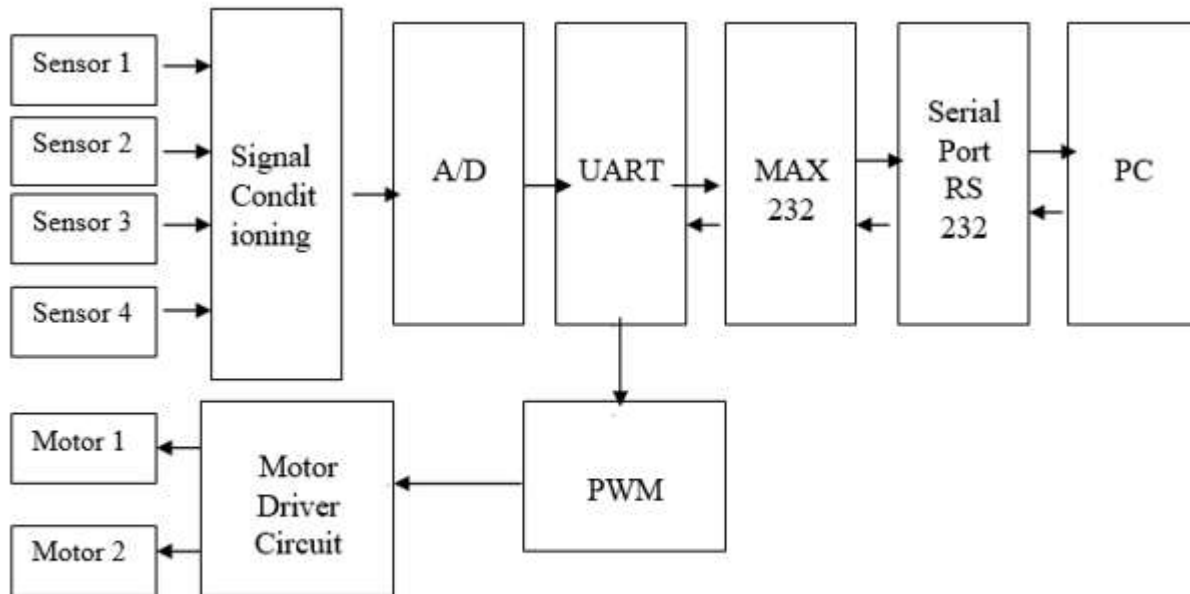


Figure 3: Block Diagram Of The Circuit.

To achieve proper dual axis motion, the motor circuit controls the direction and speed of the two engines. This circuit contains a synchronous counter, a conspirator for magnitude and a motor driver for pulse width modulation (PWM)[7]. The serial communication block encloses a UART (Universal Asynchronous Receiver transmitter)[8] equipped hardware that perfects serial to parallel communication, and vice versa and MAX 232 converts standard serial RS232 signals to / from standard TTL (0-5 V) rates.

To monitor the sensor readings and interact with the control circuit is built a program. The software reads the outputs of each sensor sequentially by sending consecutive control words to address the sensors, A control word is sent from the serial port of RS232[9] into the MAX232 where it is level-conditioned to TTL standard rates. The least important bit of the control word contains the channel address to be read for the A/D. When reading the data of all sensors, the program manipulates those data by taking the difference. The disparity in sensor readings is known to mean unequal sensor illumination. The software then sends out a word speed control io choosing the motor needed to trigger and its velocity and direction. The word speed control is sent out of the serial port of SP RS232, then the MAX232 conditioned stage-. The UART receives the word speed control and is wired to a parallel format. The least significant bits of the word tire speed control include the speed code introduces the input to the 8-bit comparator, which is compared to the counter's binary count before it reaches a count just above the speed value. At this instant, a low signal is output by the comparator which determines which motor should be active and the direction of rotation.

CONCLUSION

A fluffy knowledge-based computer operated sun tracking device is conceived in this paper. The evolved Fuzzy logic controller algorithm has a simple structure, in reality it is like controller of type P. The control signals for East-West and North-South motors are generated using a set of fourteen linguistic laws. Different experimental laboratory tests are carried out for the tracker's different initial location. These tests demonstrate the established controller's effectiveness in tracking a moving source of light.

The following points can be dealt with in the direction of tire enhancing the sun tracking:

1. A self-contained sun tracker.
2. Build a stand-alone sun tracker with micro-controller
3. The device resets at sunset.

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