Automatic Sun Tracking System (ASTS)

Muhammad Faheem Khan, Rana Liaqat Ali
Faculty of Electronics Engineering, Air University
Islamabad, Pakistan
Email: faheemkhaan@yahoo.com, ranaliaqat123@yahoo.com

Abstract— Automatic Sun Tracking System is a hybrid hardware/software prototype, which automatically provides best alignment of solar panel with the sun, to get maximum output (electricity).

Keywords: Microcontroller, RS232, Sun Tracking, Control Unit, Database.

1. INTRODUCTION

In remote areas the sun is a cheap source of electricity because instead of hydraulic generators it uses solar cells to produce electricity. While the output of solar cells depends on the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels must remain in front of sun during the whole day. But due to rotation of earth those panels can’t maintain their position always in front of sun. This problem results in decrease of their efficiency. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel.

The Automatic Sun Tracking System (ASTS) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. The unique feature of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum. In case the sun gets invisible e.g. in cloudy weather, then without tracking the sun the ASTS keeps rotating the solar panel in opposite direction to the rotation of earth. But its speed of rotation is same as that of earth’s rotation. Due to this property when after some time e.g. half an hour when the sun again gets visible, the solar panel is exactly in front of sun. Moreover the system can manage the errors and also provides the error messages on the LCD display. In manual mode, through the software (GUI) at computer, the solar panel can be rotated at any desired angle.

2. STRUCTURE OF ASTS

ASTS is a hybrid hardware/software project. Its general structural diagram is shown in figure-1.

The software includes:
- VB 6.0 based GUI.
- Microsoft Access database.
- Embedded Software (written in C) for microcontroller AT89c52.

The hardware includes:
- Solar panel assembly structure containing six functional sensors, stepper motor and solar cells.
- System Control Unit containing LCD, Keypad, Error Indicators and Emergency Stop switch.
- Complete PCB containing two microcontrollers (89c52). First one is the “Master Microcontroller” which controls the automatic operation of ASTS. While second one, the “Slave Microcontroller” serially communicates (RS232) with VB software in computer.

Figure 1. General Assembly of ASTS

1: Solar panel is a board containing many solar cells.
2: Earth rotates about 1° in four minutes.
3. WORKING OF ASTS

3.1 Basic Principle

The basic functional blocks of this system are six sensors\(^1\), and their operation depends upon the intensity of light falling on solar panel. All sensors (each with different functionality) send their output to microcontroller AT89c52. Then the microcontroller executes predefined task in its software. These sensors are being used with following names and functionality:

3.1.1 Sun Tracking Sensors (STS)

These two sensors are mounted in “V” shape (figure-2) exactly in the middle of the solar panel (figure-4). The automatic sun tracking is accomplished according to following 3-step diagram.

![Figure 2. Basic Automatic Sun Tracking Operation](image)

- Step-1 shows that when the sun is in front of solar panel, both sensors i.e. STS-1 and STS-2 are getting same amount of light.
- In step-2, after some time as the earth rotates the solar panel gets repositioned with respect to sun and STS-1 obtains less amount of light. At this point the LDR i.e. STS-1 sends signal to the microcontroller (figure 3). Then the controller\(^1\) rotates motor, resulting the rotation of solar panel towards the sun.
- Finally step-3 shows the reorientation of solar panel. The process continues until the end of day.

![Figure 3. Interface of LDR with Microcontroller](image)

3.1.2 Night Time Fault Detector (NTFD)

In routine work of the system if a general fault\(^2\) occurs during nighttime then the next morning it would not work. So at the next sunrise, this sensor detects whether the solar panel is ready for tracking or not. As shown in figure-4, the NTFD is mounted in east of the solar panel so in normal conditions it does not work because it gets lesser intense light (predefined) as compared to the middle sensors i.e. STS-1 and STS-2, but as the fault arises, it starts working.

3.1.3 Day Time Fault Detector (DTFD)

Except some special conditions e.g. cloudy weather etc, the ASTS is supposed to track the sun the whole day. If the panel stops rotation then DTFD detects this type of fault. The mounting strategy of this sensor is same as that of NTFD except that it is mounted in the west.

3.1.4 Night and Cloud Detection

In a cloudy day light intensity is less than a normal day. Similarly during night, light intensity is far less than a cloudy day. So the night and cloud sensors work on this principle to detect the event. To sense a smaller change in light intensity cloud sensor is more sensitive than the Night sensor.

*In case of Night event, the microcontroller stops all operations of the system and repositions the solar panel towards east to track the sun for next morning.*

![Figure 4. Sensor mounting assembly on solar panel](image)

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1: *Controller* would alternatively be used as the short name of microcontroller.
2: A general fault means the one that stops the rotation of solar panel.
4. CONTROL STRATEGY OF ASTS

For a successful operation, the ASTS has two types of control approach:

- Automatic Control
- Manual Control

4.1 Automatic Control

With the help of an efficient algorithm (written in C) only one Master Microcontroller is being used to manage the automatic operation of ASTS. This controller has following functions:

- Senses all of six sensors.
- Drives stepper motor.
- Drives LCD.
- Controls the warning indicators e.g. buzzer, LED’s etc.
- Communicates (by parallel port) with the slave microcontroller.

The central driving components of automatic control are only six sensors. Their operation has been explained on the previous page.

4.2 Manual Control

As no human made system is so perfect so an unpredictable fault may occur in the any system. That is why a manual control option was also kept in ASTS. While designing this part of control two objectives were kept in mind:

- The manual control should work efficiently.
- It should be as user friendly as possible.

Following two approaches have been used to accomplish the manual control.

- Stand Alone system control Unit
- Computer based control unit

4.2.1 Stand Alone System Control Unit

It is a simple user interface, which includes onboard LCD, Keypad, Buzzer and a complete PCB of the system circuit. The LCD (Hitachi HD44780) displays different messages, which can help the user in manually operating the system. While the keypad includes keys of Numeric Digits, Emergency Stop, clock wise rotation and counter clockwise rotation. Using keypad a user can manually rotate the solar panel by entering angle from 0° to 180°. The angle value is limited to only 180 values because after sunrise, the earth almost rotates only 180 degrees and then the sun disappears. The advantage of this unit is that to run the system it does not need computer but its disadvantage is that at a time it controls only one solar panel. In figure-1 this unit shown in yellow color, in middle of solar panel and computer terminal.

Figure 5. Flow Chart showing automatic operation of ASTS

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1: ASTS incorporates two microcontrollers i.e. Master Controller and Slave Controller
4.2.2 Computer Based Control Unit

This is completely software based control, written in VB 6.0. It incorporates a GUI (figure-6) and a Database, linked with Microsoft Access. Using this software the computer serially communicates (RS232) with the ASTS. The Slave microcontroller (89c51) of the system makes this communication successful. Due to some fault if the solar panel stops rotating, then with the help of this software a user can:

- rotate the solar panel manually.
- stop all operations of ASTS (in emergency case).

The database of this system can be used to keep records, which can be retrieved even after a long time. While saving the new data, the database automatically takes the date and time from the computer and keeps them saved along with the data, entered by the human being.

The advantages of computer-based control include:

- Facility of Database.
- At a time this software can handle three ASTS systems.
- It has an attracting GUI.

5. CONCLUSION

Although ASTS is a prototype towards a real system, but still its software and hardware can be used to drive a real and very huge solar panel. A small portable battery can drive its control circuitry. Therefore by just replacing the sensing instrument, its algorithm and control system can be used in RADAR and moveable Dish Antennas.

FUTURE ENHANCEMENTS

Many modifications especially in hardware of ASTS are planned:

- The computer and System Control Unit would have a wireless communication with the mechanical structure of solar panel.
- More sensitive sensors would be used.
- To make emergency control better more powerful microcontrollers e.g. PIC 16F877A would be used.
- To reprogram the PIC microcontroller a wireless boot loader would be used.

FINANCIAL COST

The cost of the end product (ASTS) may vary from country to country but in Pakistan, it costs almost US$-170, excluding the price of compiler and programmer of microcontroller.

DEVELOPMENT TOOLS

1. Software
   - KEIL C Compiler (for 8051 microcontroller family).
   - VB 6.0
   - Microsoft Access

2. Hardware
   - SUPERPRO L+ Universal Microcontroller Programmer

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![Figure 6. VB based GUI of ASTS](image)