Application case - Solar tracking system

The Solar Energy

The industrial development over the past few decades greatly improved the food, clothing, shelters and transportation in the world. However, the advancement in industries accompanies ever-increasing energy consumption and pollution, and therefore, using renewable energy and reducing energy waste and are the primary issues.

The solar energy is one of the renewable energy, Making good use of it not only will solve the energy shortage problem, but also greatly reduce pollution and ease the effects of global warming..

There are currently two ways to generate electricity from solar energy:

1) Converting solar energy to electricity; 2) Converting solar energy to heat, then heat to electricity
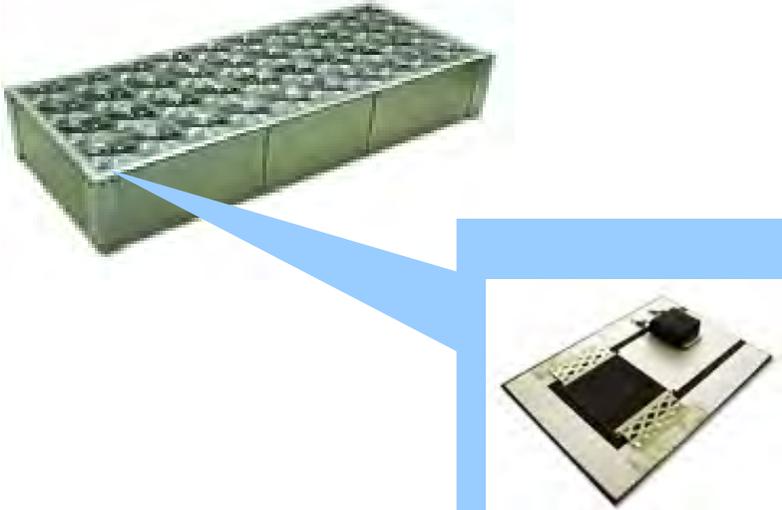
Solar energy to electricity

Solar energy to heat, heat to electricity

1. Converting solar energy to electricity

The solar energy converts the energy from sun to electricity. The medium for conversion are PV (Photovoltaics) and CPV (Concentrated Photovoltaics). The fixed angle is primary to the installation of PV. The installation of CPV has to work with 2-axis devices due to the area of power generation medium. Following the earth rotation, CPV adjusts the angle of the solar panel to the best one according to the incident angle of sunlight.

PV (Photovoltaic)	CPV (Concentrated Photovoltaic)
	 CPV

1.1 PV

Most PV solar panels face the sky from a fixed angle or are driven by a single axis (east <-> west). Electricity can be generated by direct or indirect (scattered) sunlight.

Fixed solar panels

Single-axis solar panels

1.2 CPV

Most CPV solar panels are driven by 2 axes (horizontal angle and pitch angle). The angle to catch sunlight is calculated by the host controller, bringing forth the best vertical angle between the sunlight and the panel and further driving the 2 axes to rotate and enhance the efficiency of electricity generation.

## 2. Converting solar energy to heat, then heat to electricity

The big reflecting mirror gathers beams of light into one light tower where liquid sodium is stored. When the temperature in the tower rises, steam will be generated to push the turbine inside it to further generate electricity.
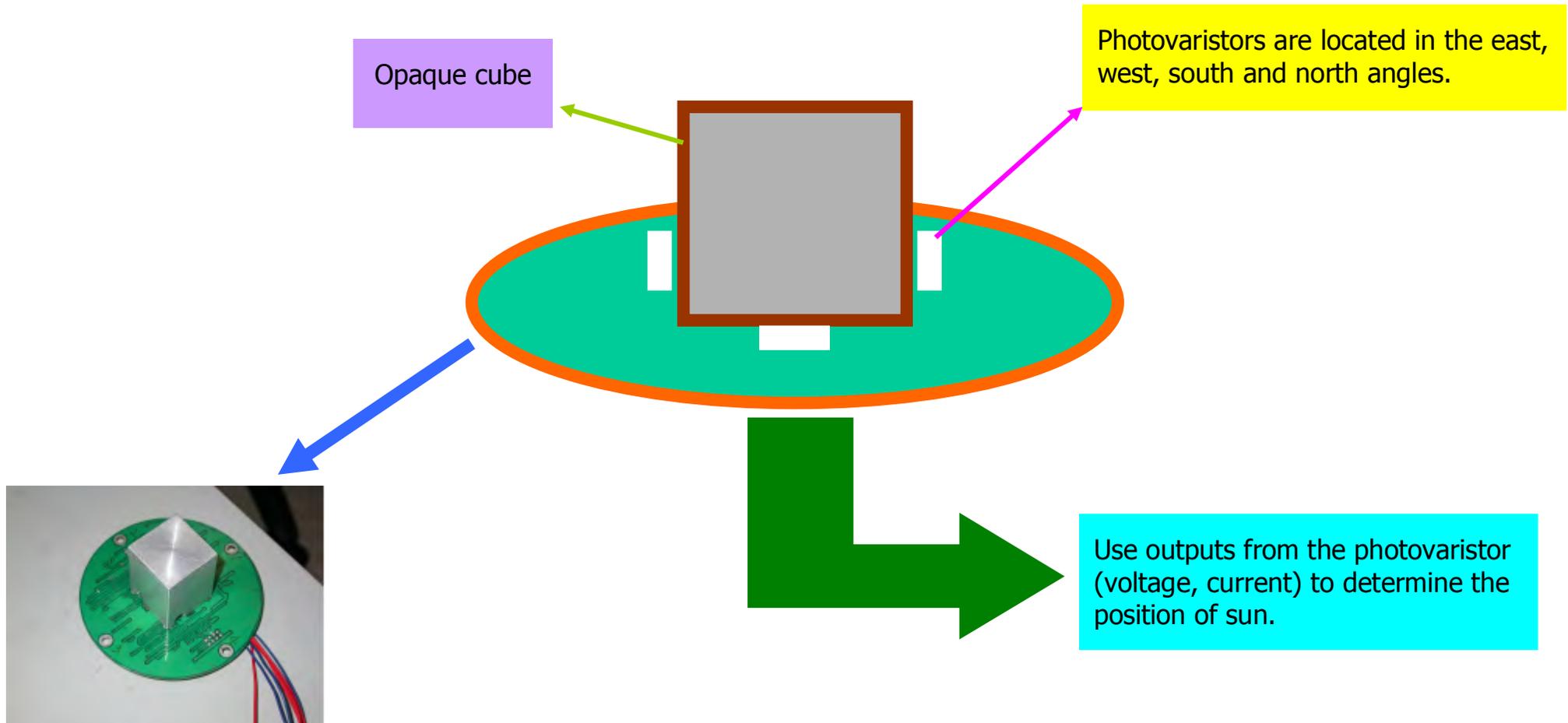
3. Structure of a Solar Tracker

3.1 Open-loop calculation

With the GPS sensor and latest GPS/SPA commands developed for Delta's new DVP-ES2/EX2/SX2/SS2 series PLC, the pulse output controls the positioning of the 2 axes, and the encoder feedbacks the position of the panel in order to accurately acquire the position of the solar panel, allowing the largest amount of solar energy reception. The 3 independent communication ports built in DVP-ES2/EX2 series PLC are responsible for monitoring the controller and sending/receiving signals.
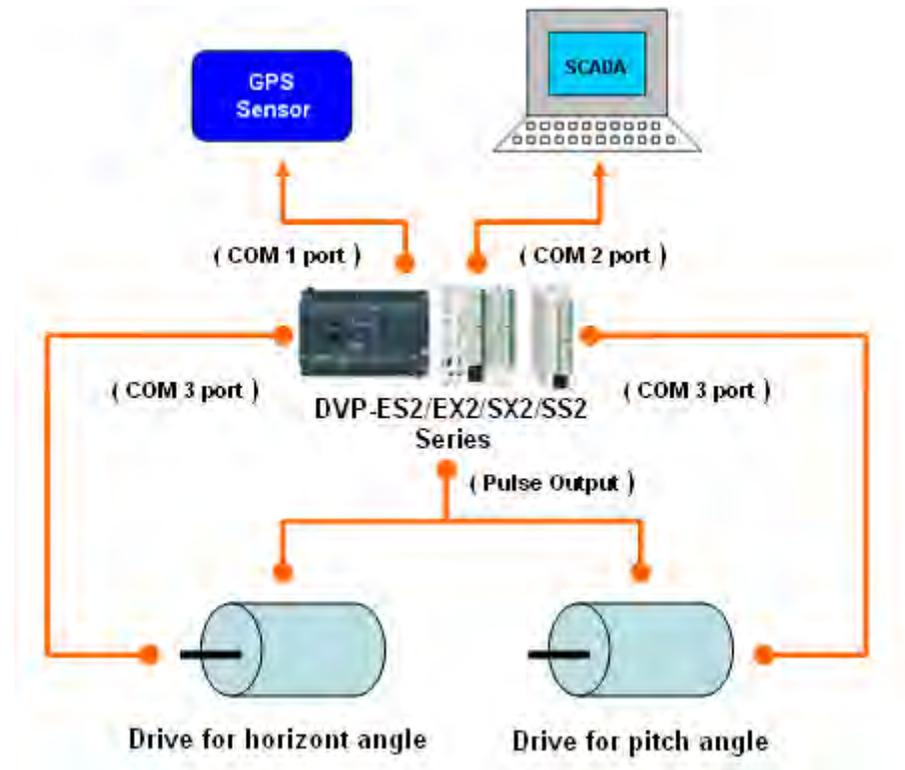
3.2 Close-loop calculation

Using the open-loop calculation to track the sun is easily limited by the earth's environment and devices in the solar tracker (e.g. abrasion and aging of them), resulting in inaccurate positioning of the sun after using SPA calculation to get the horizontal and pitch angles. Therefore, we use photovaristor for the solar tracker to detect the amount of sunlight and further adjust its angle.

Opaque cube

Photovaristors are located in the east, west, south and north angles.

Use outputs from the photovaristor (voltage, current) to determine the position of sun.

3.3 Hybrid calculation

In real practice, when open-loop or close-loop calculation is used separately, the efficiency to generate electricity by the solar tracker will be easily affected by the devices installed in the tracker or the weather. However, if we combine the open-loop calculation with the close-loop calculation, they will exert their advantages while making up for each other's disadvantages. For example, the tracker will switch to the close-loop mode on sunny days and open-loop on cloudy days, allowing the panel to track the sun by SPA calculation all the time.
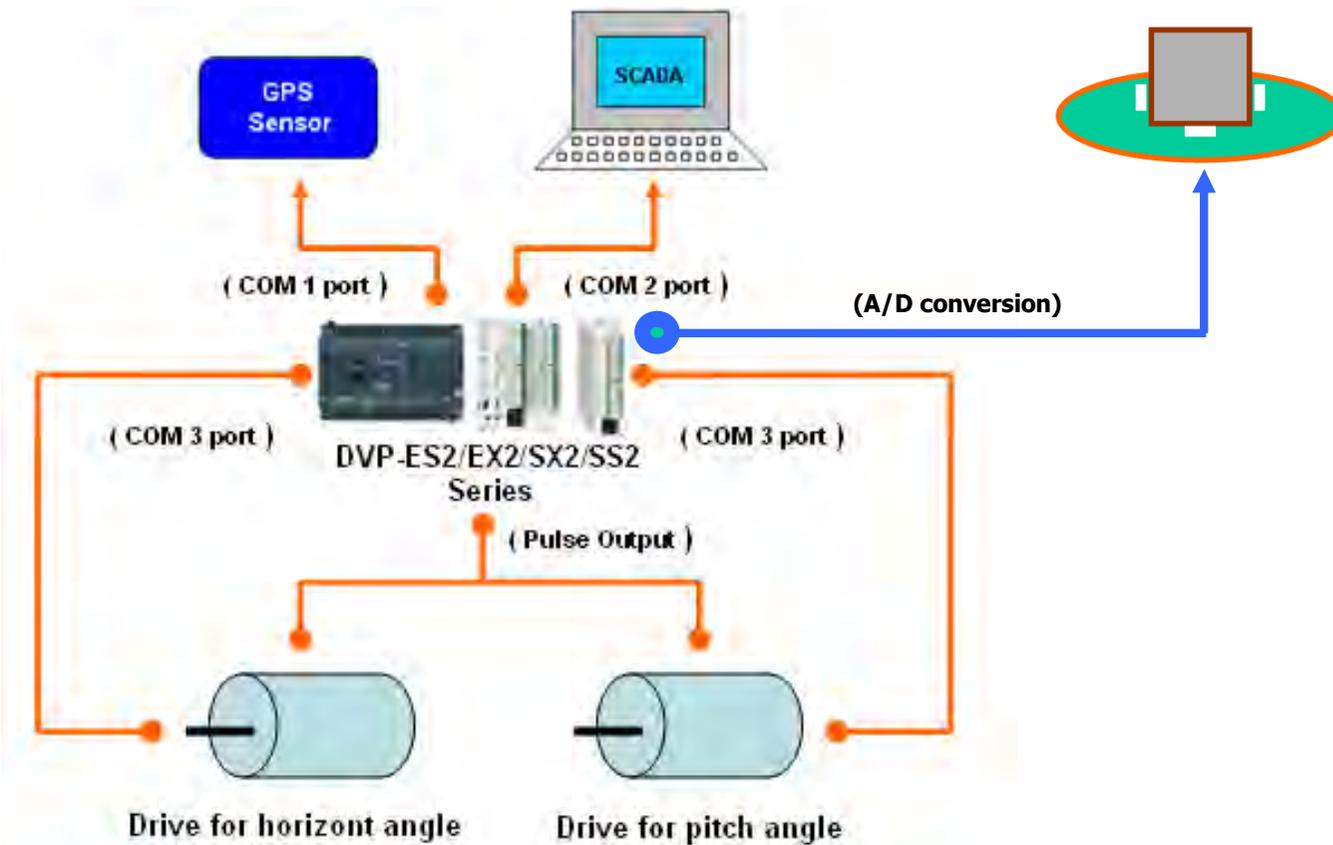
4. GPS sensor

4.1 LS 20022 GPS sensor: (Communication Protocol=NMEA-0183 → version 3.0, frequency→1Hz)
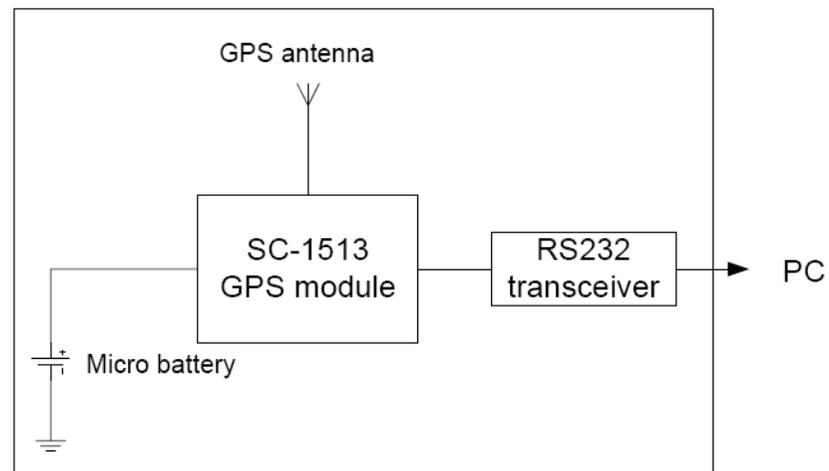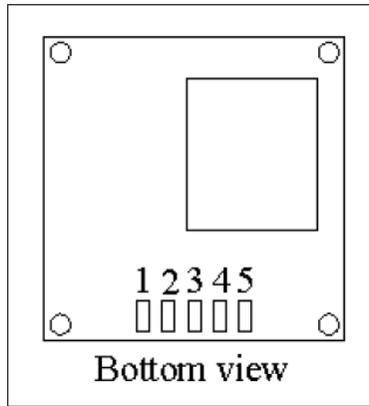

Top View

LS20022

4.2 Specification of circuit:

4.3 Pin definition: (Communication Protocol → 9600, 8, N, 1)

Bottom view

Pin #	Name	Type	Description
1	VCC	P	Power input
2	RX	I	Data input (RS232 level)
3	TX	O	Data output (RS232 level)
4	GND	P	Ground
5	GND	P	Ground

5. Functions for Solar Tracker in DVP-ES2/EX2/SX2/SS2 series PLC

5.1 Global Positioning System (GPS)

Operands: GPS S D   →Only supports 16 bits
Compatible COM port: COM1 (RS-232)

Explanations:
S: The input number can only be "K0" and "K1". K0 receives format of $GPGGA; K1 receives format of $GPRMC.
D: The storage area for received data. It will occupy 17 consecutive registers and these registers cannot be overlapped. The following chart is the outcome of K0 and K1 in the S operand.

When **S** = K0, **D** will be:

Register No.	Definition	Range	Data type	Comment
D + 0	Hour	0 ~ 23	Word	
D + 1	Minute	0 ~ 59	Word	
D + 2	Second	0 ~ 59	Word	
D + 3	Latitude	0 ~ 90	Float	dd.mmmmmm
D + 5	Latitude of North or South	0 or 1	Word	0(+)→North, 1(-)→South
D + 6	Longitude	0 ~ 180	Float	ddd.mmmmmm
D + 8	Longitude of East or West	0 or 1	Word	0(+)→East, 1(-)→West
D + 9	Received Data is valid or invalid	0, 1, 2	Word	0→invalid
D + 10	Elevation	0 ~ 9,999.9	Float	Unit: Meter
D + 12	Latitude	-90 ~ 90	Float	Unit: ±dd.ddddd
D + 14	Longitude	-180 ~ 180	Float	Unit: ±ddd.ddddd

When **S =** K1, **D** will be:

Register No.	Definition	Range	Data type	Comment
D + 0	Hour	0 ~ 23	Word	
D + 1	Minute	0 ~ 59	Word	
D + 2	Second	0 ~ 59	Word	
D + 3	Latitude	0 ~ 90	Float	dd.mmmmmm
D + 5	Latitude of North or South	0 or 1	Word	0(+)→North, 1(-)→South
D + 6	Longitude	0 ~ 180	Float	ddd.mmmmmm
D + 8	Longitude of East or West	0 or 1	Word	0(+)→East, 1(-)→West
D + 9	Received Data is valid or invalid	0, 1, 2	Word	0→invalid
D + 10	Date	1 ~ 31	Word	
D + 11	Month	1 ~ 12	Word	
D + 12	Year	2,000 ~	Word	
D + 13	Latitude	-90 ~ 90	Float	Unit : ±dd.ddddd
D + 15	Longitude	-180 ~ 180	Float	Unit : ±ddd.ddddd

(1) The GPS command can only be used on RS-232 COM 1 Port. Its communication format is "9600, 8, N, 1" and communication protocol is NMEA-0183 v3.0, frequency is 1Hz.

(2) When utilizing the COM 1 port as Master mode in the GPS data receiving, you have to set M1312 to be on. Then, M1314 will be turned on after the data receiving is completed. However, the data receiving may not always be successful. Thus, M1315 will be on if while the receiving is incomplete. If so, you can check D1250 for details. (D1250 = K2: checksum error; D1250 = K1: receiving time-out)

(3) Definitions of related special M and special D:

Special M	Definition
M1312	Sending request
M1313	Waiting for receiving
M1314	Receiving is completed
M1315	Receiving time-out
M1138	Retaining COM1communcation format
D1036	COM1 communication format
D1249	Communication time-out setup
D1250	Error code

(4) It's recommended that you check the value of D+9 whether it is valid or not before using the Latitude and Longitude values.

(5) The values stored in operand D will show the last successful data receiving result.

Template: Use S = K0 to receive format of $GPGGA
See below for COM1 communication format and the ladder program of PLC:

```
      M1002
──────┤ ├──────┬──────────────────────────┐
                │        MOV   H81   D1036  │   9600,8,N,1
                │        └──────────────────┘
                │
                ├──────────────────────────┐
                │        MOV   K2000  D1249 │   Time out 2sec
                │        └──────────────────┘
                │
                └──────────────────────────┐
                         SET   M1138        │   Fix COM1 protocol
                         └──────────────────┘
```
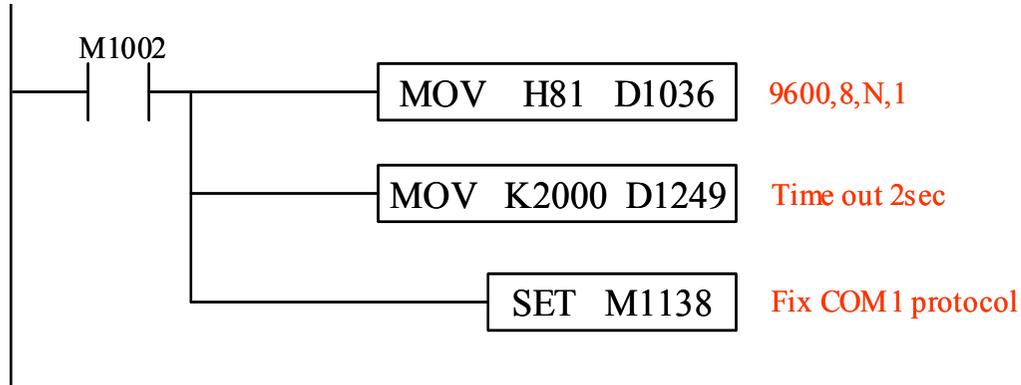
Set M0 to "ON" to start receiving the data of $GPGGA

```
       M0
──────┤↑├──────────────────────────┐
                  SET   M1312        │
                  └──────────────────┘

       M0
──────┤ ├──────┬────────────────────┐
                │     GPS    K0    D0 │
                │     └───────────────┘
                │
       M1314    │
       ├ ├──────┤──────────────( Y0 )
                │
       M1315    │
       ├ ├──────┤──────────────( Y1 )
```
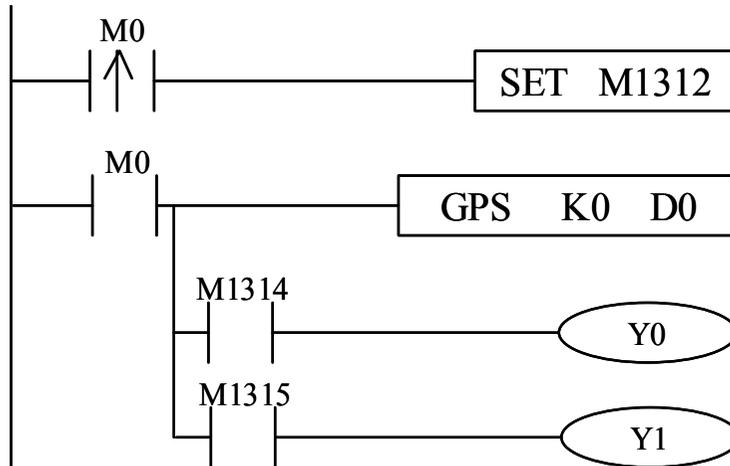
M1314 will be "ON" if the data receiving is successful, and the received data will be placed in registers starting from D0. M1315 will be "ON" if the data receiving fails.

5.2 Solar Position Algorithm (SPA)

Operands: DSPA S D; only supports 32 bits
Explanations:

(1) **S** will occupy 207 consecutive registers. See below for the definition.

Register No.	Definition	Range	Data type	Comment
S + 0	Year	2,000 ~	Word	
S + 1	Month	1 ~ 12	Word	
S + 2	Day	1 ~ 31	Word	
S + 3	Hours	0 ~ 23	Word	
S + 4	Minute	0 ~ 59	Word	
S + 5	Second	0 ~ 59	Word	
S + 6	Time accuracy ($\triangle$t)	±8,000	Float	
S + 8	Local time	±12	Float	Negative value(-) if the area is in Longitude of West
S + 10	Longitude	±180	Float	Negative value(-) if the area is in Longitude of West Unit: Degree
S + 12	Latitude	±90	Float	Negative value(-) if the area is in Latitude of South Unit: Degree
S + 14	Elevation	0 ~ 6,500,000	Float	Unit: Meter
S + 16	Atmosphere Pressure	0 ~ 5,000	Float	Unit: Milli-bar
S + 18	Average Temp. of year	-273 ~ 6,000	Float	Unit: ℃
S + 20	Surface Slope	±360	Float	
S + 22	Rotated degree of azimuth	±360	Float	
S + 24	The difference of atmosphere pressure of sunrise and sunset	±5	Float	
S26 ~ **S**207	Preserve area for system using only			

(2) **D** will occupy 8 consecutive registers. See below for the definition.

Register No.	Definition	Range	Data type	Comment
D + 0	Zenith	0 ~ 90	Float	Parallel with ground is 0 degree
D + 2	Azimuth	0 ~ 360	Float	Right in the North is 0 degree
D + 4	Incidence of panel surface	0 ~ 90	Float	
D + 6	Zenith convert to 0 ~ 10V of D/A	0 ~ 2,000	Word	1LSB = 0.045 degrees
D + 7	Azimuth convert 0 ~ 10V of D/A	0 ~ 2,000	Word	1LSB = 0.18 degree

(3) **S** and **D** cannot be put into any devices except for D registers
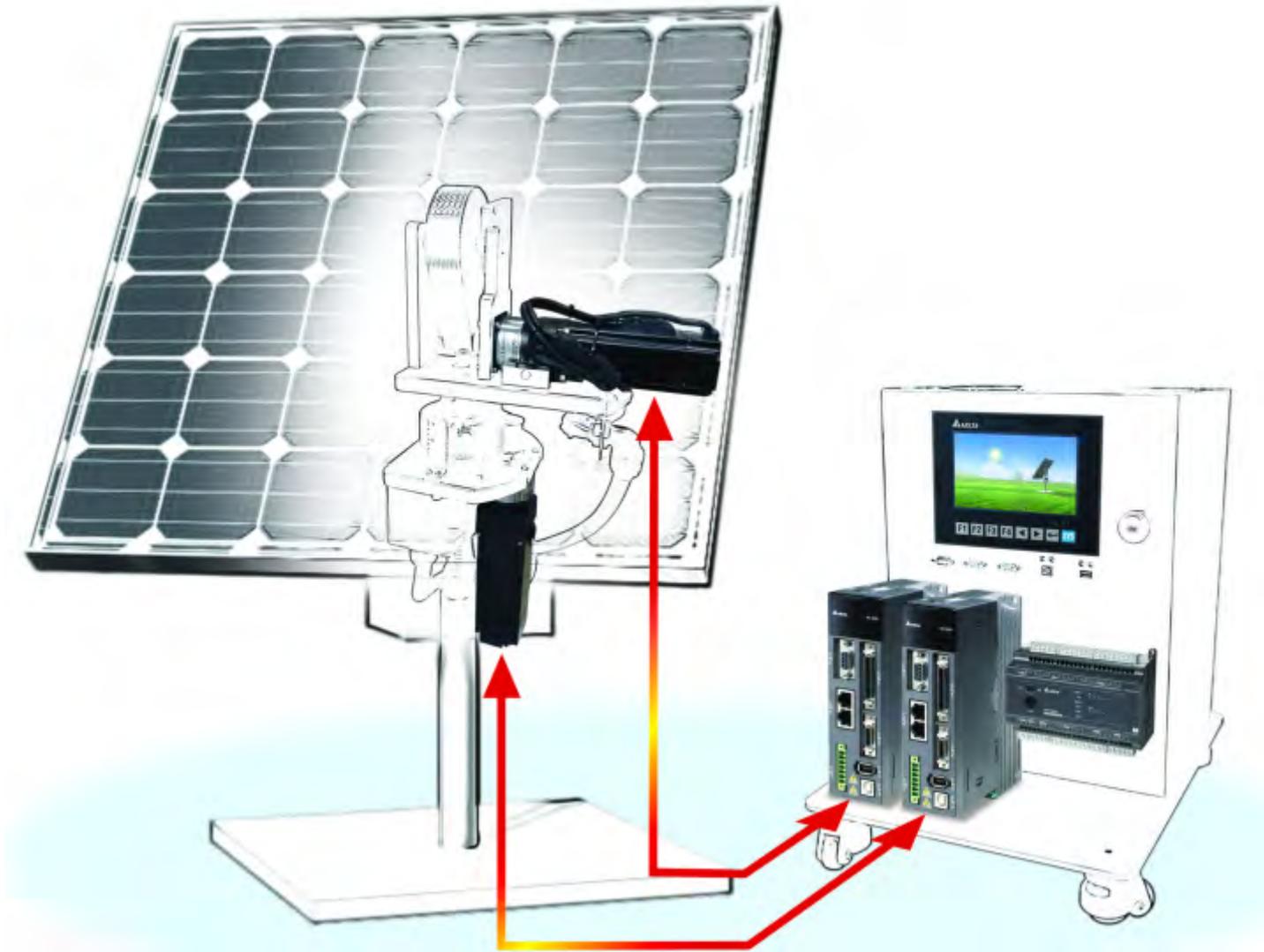
(4) Due to that the DSPA command will consume 50ms operation time, we suggest the user display this command every second (or longer than 1s) to avoid spending too much PLC operating time.

6. Applying Delta's industrial automation products in solar trackers

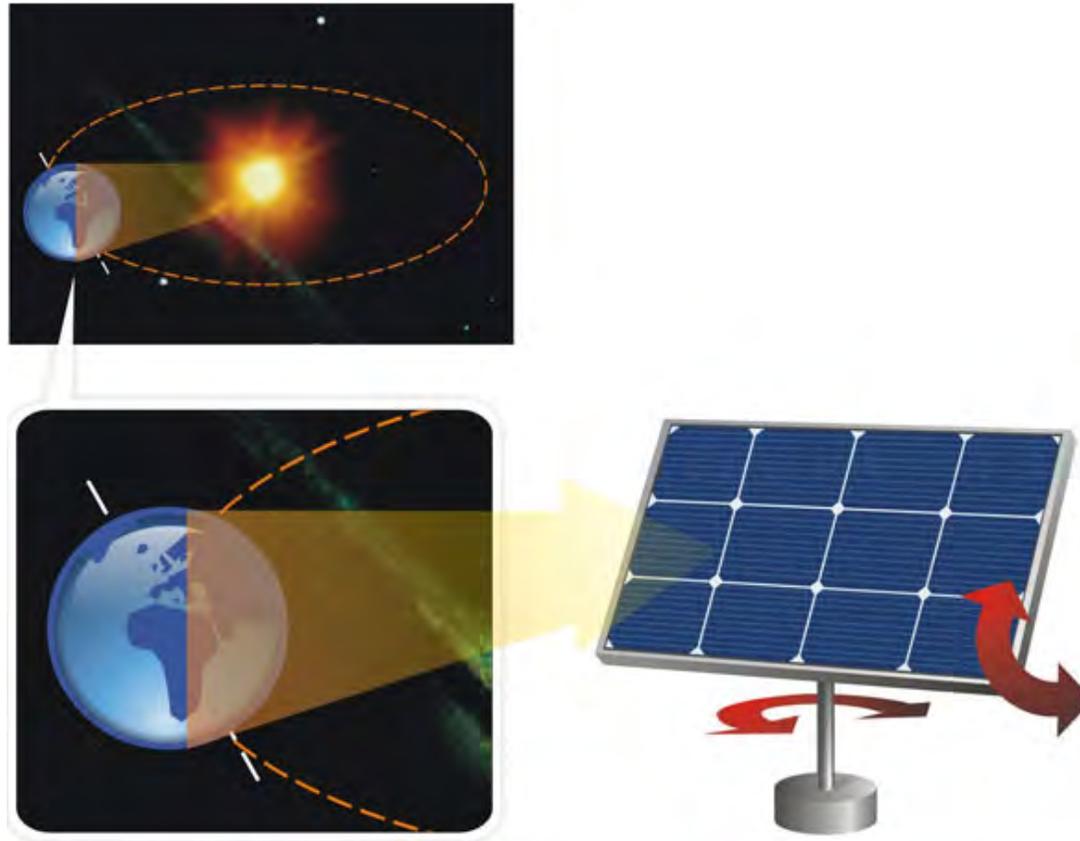## 6.1 The single-axis solar tracker

6.2 Double-axis solar tracker
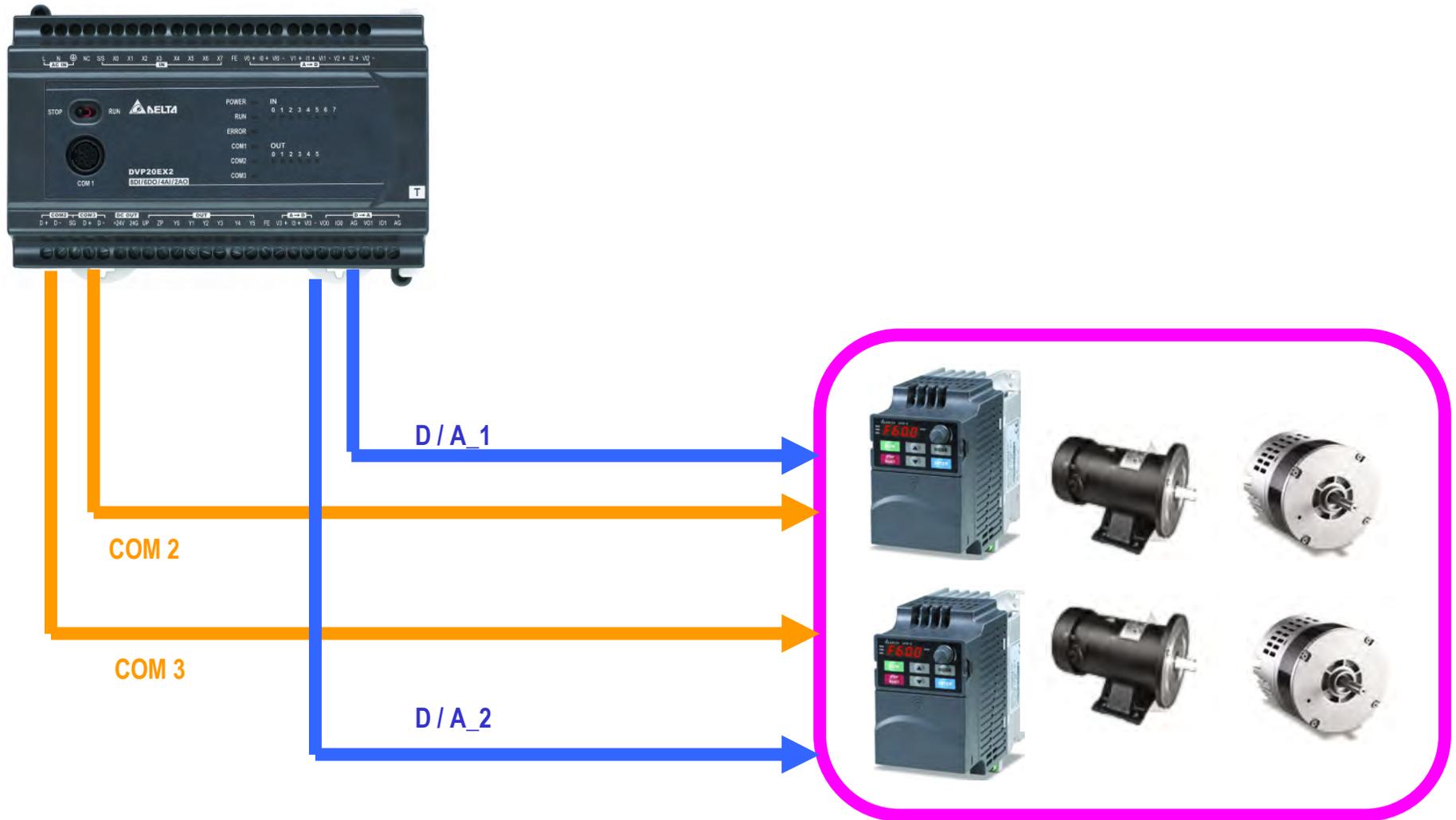
7. Drives in Solar Trackers

The Earth's orbit around the sun is fixed and slow. Therefore, we have to select proper drives of the right horsepower to adapt to the size of the solar panel. The selection of drives can be DC motors, AC motors and drives, servo motors and drives.

If DC motors are adopted, output points on Delta DVP-ES2/EX2 series PLC can be used as the controller to control the output voltage and drive the DC motor.

In selecting frequency inverters and AC motors, the D/A function or RS-485 communication commands in Delta-EX2 series PLC are suitable for the control over the frequency inverter and driving the AC motor connected to it.

In selecting servo drives and servo motors, the pulse output commands, e.g. PLSR, PLSY, DDRVI and DDRVA in DVP-ES2/EX2 series PLC are perfect for accurate positioning.

Thank You