Remote sun tracing and solar energy generation system

W C Huang¹, M C Chiu²,¹*, L J Yeh¹ and L M Yeh¹

¹Department of Mechanical and Materials Engineering, Tatung University, No. 40, Sec. 3, Zhongshan N. Rd., Taipei City 104, Taiwan
²Department of Intelligent Automation Engineering, Chung Chou University of Science and Technology, No. 6, Lane 2, Sec. 3, Shanjiao Rd., Yuanlin City, Changhua County 51003, Taiwan
*Email: mcchiu@gm.ttu.edu.tw

Abstract. This paper aims to generate the most electricity on a solar board. A hemisphere sun-tracing-module composed of small solar boards is established. According to the electrical voltages of the small solar boards, the coordinates (angles) of the solar board with maximal electrical voltage will be recognized by the server port. With this, the server port will send the information to the client ports (the solar energy generation stations) via the internet. The client ports that wirelessly (with Wi-Fi module) connect to the individual microcontroller will direct the microcontroller to trigger two step motors to rotate to the related coordinates. All the main solar boards will be simultaneously adjusted to the best direction to generate the maximal solar electricity. The generated electricity will be stored in the related storage battery. For every time interval, the new coordinate will be recognized by the sun tracing module and then forwarded to the solar energy generation stations. The time interval can be predetermined on the server port.

1. Introduction

Oil and coal, the main source of energy primarily tremendously and unlimitedly used in the whole world, will be expected to exhaust in near future. Renewable energies such as wind energy, hydro energy, biomass, geothermal energy, solar energy derived from natural processes are then regarded as an alternative energy since the realization of fossil fuels shortcomings [1]. Actually, renewable energy in the form of electricity has been adopted in use to some degree 75 or 100 years ago [2]. Solar energy, a free, practically inexhaustible green energy, is sustainable, highly reliable and requires little maintenance [3]. No polluting residues or green gases emissions will exist when using the solar energy. However, the output of the solar panel is variable. Several researches of solar systems focused in how to extract the maximum amount of power available from the solar panels and deposit it in the battery. Nobert et al. suggested that solar tracking system is one of the methods to increase the efficiency of photovoltaic systems [4]. Sun tracking systems have been studied with different applications to improve the efficiency of solar systems by adding the tracking equipment to these systems through various methods [5, 6]. There are three main types of solar tracker drives, including passive tracker, active tracker, and open loop tracker [7]. Passive tracker uses a low boiling point compressed gas fluid that is driven to one side or the other to cause the tracker to move in response to an imbalance [8]. Active tracker moves the tracker using electric or hydraulic drives and some type of gearing or actuator. And, open loop tracker will determine the position of sun through pre-recorded data for a particular site. Parmar et al. investigated that a solar tracker working has an increment in the electrical output of photovoltaic modules by 25% compared to modules on fixed mounts [9]. Here, to obtain larger solar electricity, active sun tracker has been widely adopted.
The first automatic solar tracking system was presented by McFee [10, 11]. This tracking system makes the solar photovoltaic panels perpendicularly facing the sun and therefore more solar energy extracted and so the efficiency of the solar photovoltaic panels increased [12]. Here, the photovoltaic (PV) system, a well-recognized and widely-utilized system, generates direct current (DC) electricity without environmental impact and emission. The DC power can also be converted to AC power with an inverter, to power local loads to the utility [13]. Tudorache and Kreindler [14] presented a single axis solar tracker system by automatically searching via a DC motor. The use of single-axis tracking can increase the electricity yield by as much as 27% to 32% [15]. Wichert et al. revealed that the efficiency of single axis tracking is 23% which is higher than the fixed panel & passive solar tracking [16]. The research in Banerjee [17] revealed that dual axis trackers tracking the sun both east to west and north to south can provide power output of about 40%. Sadyrbayev et al. proposed a sun tracking system using 4 photo resistors, which are mounted on the sides of the photo module. A comparative analysis between fixed and dual-axis tracking systems revealed that the dual-axis solar tracking system produced 31.3% more power compared with stationary photo module [18]. According to the experimental measurements from Rhif [19], this automatic dual axis sun tracker increases the power production by over 40%. The experimental result from Sarker et al. indicated that the energy surplus becomes about (30-45%) due to atmospheric influences when using two-axis sun tracking systems on the electrical generation of a flat photovoltaic system (FPVS) [20]. As mentioned above, the solar tracking system will search a best projection direction of the sun light before it is adjusted to an appropriate angle to generate the sun electricity. It is inefficient for electricity generation with a solar generator only. Therefore, to generate sufficient electricity, a solar energy generation system using lots of solar generation units is necessary. In addition, to obtain maximal electricity, a solar tracking system used to guide the projecting direction of the solar generation units is also required. In this paper, a remote sun tracing and solar energy generation system using a sun tracking system (the server port) in conjunction with the solar energy generation stations (the client ports) is presented. Here, a hemisphere sun-tracing-module composed of small solar boards is established. According to the electrical voltages of the small solar boards, the coordinates (angles) of the solar board with maximal electrical voltage will be recognized by the server PC. With this, the server PC with Wi-Fi module will send the information to the client ports (the solar energy generation stations) via the internet. The client port which is composed of Arduino Mega 2560 and a Wi-Fi module (ESP8266) will directly trigger two step motors of the solar energy generation units to rotate to the related coordinates. All the main solar boards in the solar energy generation stations will be simultaneously adjusted to the best direction to generate the maximal solar electricity.

2. Remote sun tracing and solar energy generation system
As indicated in Figure 1, the remote sun tracing and solar energy generation system includes a sun tracking system (the server port) in conjunction with the solar energy generation stations (the client ports). The sun tracking system is composed of a hemisphere sun-tracing-module and microcontrollers. And, the solar energy generation stations (the client ports) is composed of lots of solar energy generators as well as the electricity storage unit. The two-axis step motors used to drive the solar board is controlled by microcontrollers - Arduino Mega 2560 shown in Figure 2. Here, hemisphere sun-tracing-module will detect all the specified coordinates (spherical angles of θ and Φ) using a small solar board attached onto the hemisphere rack once in an hour. And, the related electric voltage of the small solar board received by the microcontroller will be obtained. The coordinates with respect to the maximal electrical voltage will be searched and fed back to the internet cloud via the Wi-Fi (ESP8266) and the blink platform. Here, the blink platform shown in Fig. 3 is an interface built in the cell-phone Subsequently, the best projection coordinate identified from the server port will be transferred to the remote client ports via the internet network. Based on the best coordinate recognized by the sun tracking system, the solar board’s step motor triggered by its microcontroller, a client port, will adjust their solar board’s projection angle in the solar energy generation stations. The generated electricity will then be charged into the related electricity storage unit. To assure the operation safety of the solar energy generation stations, a monitoring system using IPCAM via internet is also established.
Figure 1. The remote sun tracing and solar energy generation system includes a sun tracking system (the server port) in conjunction with the solar energy generation stations (the client ports).
3. Human/machine interface
Using the RS-232 communication standard, blynk platform, and Wi-Fi protocol, the server port is wirelessly connected to the remote microcontroller (single chip). Here, the server port with a microcontroller connects to the actuators (two step motors in two axes) and the electricity voltage generator of the solar board. To remotely initiate the sun tracing and solar energy generation system and visually monitor the site situations, an app interface of blynk built in the user’s cell phone is required and shown in Figure 3.

4. Results and discussions
The remote monitoring/controlling sun tracking and electrical generation system has been accomplished. A small solar board used to generate electrical voltage is installed onto the rack of sun tracking system and connected to the microcontroller. The trace of solar board has been preset to visit several coordinates per hour by driving both the horizontal step motor and vertical step motor around the hemispheric surface. The related electrical voltage generated from the small solar board will be online detected and
recorded. These data will be shown in the LCD display online. After finishing the tracing work, the best angle set with respect to the maximal voltage will be searched and then be feedback to the blynk’s cloud in a way of wireless connection to the router (a movable AP) via the Wi-Fi module installed inside the microcontroller (Arduino 2560). The program and hardware of the sun tracking system (the server port) are depicted in Figs. 4-5.

```c
void loop()
{
    Blynk.syncVirtual(V2);
    Blynk.syncVirtual(V3);
    Blynk.syncVirtual(V6);
    Blynk.run();

    int test2 = digitalRead(42);
    digitalWrite(bm1, LOW);
    digitalWrite(bm2, LOW);
    digitalWrite(bm3, LOW);
    digitalWrite(bm4, LOW);
    digitalWrite(tm1, LOW);
    digitalWrite(tm2, LOW);
    digitalWrite(tm3, LOW);
    digitalWrite(tm4, LOW);
    for (int f = 0; f < 100; f++)
    {
        float v_value=analogRead(A0);
        j=v_value*7.05/1280;
        k=j;k;
    }
    k=k/0.1;
    for (int q = 0; q < 100; q++)
    {
        float a_value=analogRead(A1);
        l=a_value/2368;
        p=l+p;
    }
    p=p/0.1;
```

**Figure 4.** The program (abstracted) for the server port’s microcontroller.

Observation of the system’s running test reveal that the best angle set is passed to the microcontroller of the client port from the blynk cloud via the Wi-Fi protocol. And, both the horizontal and vertical step motors have been triggered to rotate the big solar board to the specific coordinate. The generated electricity has also been saved onto the electricity saving unit. The program and hardware of the electricity generation plant (the client port) are depicted in Figures 6-7. Consequently, a prototype of the sun tracing and solar energy generation system is accomplished.
5. Conclusion

It has been shown that a wireless sun tracing and solar energy generation system can be remotely monitored during the solar energy generation process. Using the RS-232 communication standard and Wi-Fi protocol, the server port can be wirelessly connected to the internet cloud. The microcontroller of the server port connects to two step motors and the small solar board. For the manpower saving issue, the system is designed to automatically and periodically trace the sun (server port) and then generate the solar energy (client port). With the help of sun tracking system, the solar generation station can be always toward to the best (maximal) sun light projecting direction. Therefore, the electricity generated from the solar boards will be maximized. To assure the safety during automatic solar generation process, a visual monitoring in site using IPCAM is established. Consequently, a wireless sun tracing and solar energy generation system is demonstrated and practically accomplished.
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