Installation of Solar Energy Cloud Management System and its Case Analysis

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Abstract: **This study constructs a solar energy Cloud management system, which is aimed at "equipment monitoring, system management, and data analysis". A remote monitoring system and equipment monitoring network platform is designed to achieve remote monitoring and electric energy management, where the software and hardware equipment are integrated by a serial communication converter and the RS485 communication interface and Ethernet feedback the related power generation data to the server for backend personnel to manage data. The installed capacity of the photovoltaic system in this laboratory is 70.38kWp, which is connected to the grid as the laboratory lighting system. The relationship of the elevation angle and azimuth of the sun to the power generation module angle is examined.**

Index terms: **photovoltaic system; cloud; Mod bus-protocol; the elevation angle**

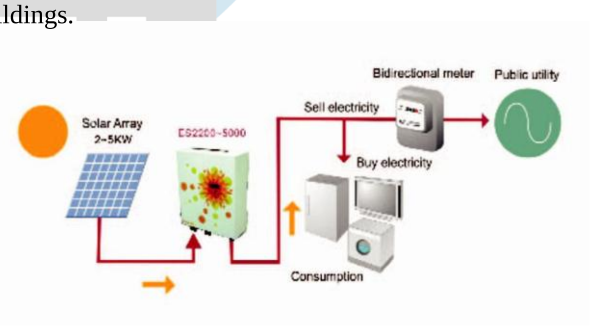
I. INTRODUCTION

The world energy requirement is ever growing particularly since the last few centuries. Since the use of energy has become an integral part, its supply should be secure and sustainable. At the same time, it would be economical, environmentally friendly and socially acceptable. The rising consumption of fossil fuels, together with increasing greenhouse gas emission, threatens our secure energy supply. Facing the exhaustion of energy and petroleum resources, the development of new energy has been an inevitable topic for humans, including solar energy, wind energy, biomass energy, oceanic tides, etc. Therefore, there is a need for alternative energy sources which can provide as energy in a sustainable manner. The obvious choice of a clean energy source, which is abundant and could provide security for the future development and growth, is the sun's energy. Solar power is the most obtainable and inexhaustible, thus, if its generating efficiency can be increased, it must become the mainstream power generation of the future. As Taiwan is an island, it must import a lot of raw materials to obtain energy, thus, the government has proposed the "Million Solar Roofs" project in order to promote a photovoltaic system [1]. The installed capacity of the planned photovoltaic system is to be 6,200MW in 2030. This laboratory is equipped with a photovoltaic generation system for teaching and power supply. At present, many high schools, elementary schools, and houses are equipped with PV generation systems in Taiwan. However, as the enormous amount of investment has not been properly managed, the system has not performed effectively.

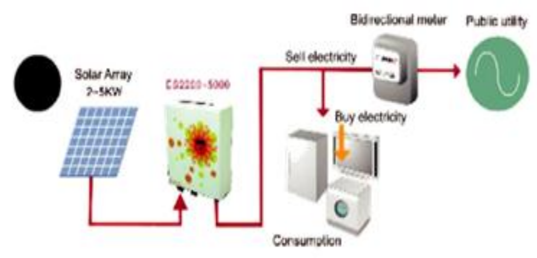
In terms of practical administration, in addition to Cloud monitoring, maintaining good operations of the PV generation system through equipment maintenance is an important factor of engineering, including the characteristics and conversion efficiency of solar cells[2-3], PV module cleaning, leveling of photovoltaic panel glass surface, the effect of module temperature, shadow, loss of power transmission, conversion efficiency of inverter, electromagnetic interference of communication line, correction of smart meters, etc. In order to know the power generation condition and monitor various data, a user-friendly monitoring system that meets modern demands is designed to increase the overall effectiveness of green energy generating equipment.

II. PV GENERATION SYSTEM

This study includes a grid-connected PV generation system, which generates power for daytime loads, and power shortages are supplied by the Taiwan Power Company. At night, all power is supplied by the Taiwan Power Company. This system is installed on the top floor of the Complex Building, National Taipei University of Technology, and includes the north, middle, and south buildings.



(a)



(b)

Figure 1:(a) Power generation in the daytime (b) Grid power supply at night

Figures 2 and 3 shows the field modules, including the fixed module and horizontal one-axis sun tracking module.

Figure 2: Fixed module

Figure 3: Horizontal one-axis sun tracking module (east-west)

1. System framework and monitoring process

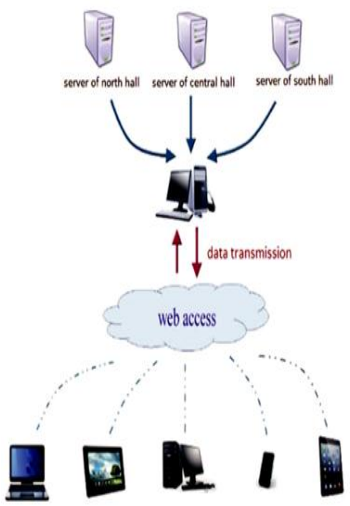


Figure 4.The schematic diagram of the system framework.

The Meter DCS, ModScan32, and Web access software programs implement monitoring for effective electric energy management. Finally, the data are displayed on the developed network platform and the school entrance billboard. Figure 4 shows the schematic diagram of the system framework.

2. Advantech Web Access

Advantech Co., Ltd. released Web Access 7.1 in 2013. Web Access is the first browser-based HMI/SCADA software in the world. The latest Version 7.1 has made great progress in the field of remote multi-website management. Based on Version 7, Version 7.1 reduces the installation process, and is integrated with Google Maps™, a real-time database, a DiagAnywhere server remote connection and configuration, and other 3500-engineering drawing libraries, thus, improving the full performance of the SCADA system. Web Access 7.1 has a new function; the built-in DiagAnywhere Client can be connected to any equipment server equipped with DiagAnywhere, meaning that engineers can remotely monitor locally obtained detailed data, such as memory consumption, temperature, voltage, etc.

III. REMOTE MONITORING EQUIPMENT

1. Cloud server

The server used in this study is ASUS RS300-E8-PS4. The server is equipped with UPS as an emergency supply in order to enhance the stability and reliability of the network platform, and the 2TB capacity can store mass data for administrators to implement historical review or data analysis.

2. Data transmission equipment

The serial communications converter is provided by Info system Technology Corporation, Ltd., which replaces the original RS-485 communication. In addition, a RS-232 and a RJ-45 network connection are provided, which are applicable to intercommunication protocol, such as the Modbus communication protocol. The physical device is as shown in Figure 5.

Figure 5: M3280 metering converter.

1) Hardware at Master end: LAN (Modbus/TCP), RS232, RS485.

2) Equipment side: RS485 (RTU).
3) PC side: the data of the equipment side can be shared by connecting the three sides, where the data transmission protocol is Modbus TCP or Modbus RTU.

This device provides RJ-45 and three COM Ports. COM1 and COM3 of the three COM Ports are connected to the Modbus Master, while COM2 is connected to the Modbus Slave. COM1 is RS232, and COM2 and COM3 are RS485, as shown in Figure 6. TCP, COM1, and COM3 can share the data of COM2. As this device temporarily stores commands, there is no conflict when the Master reads Slave data, thus, implementing data sharing.

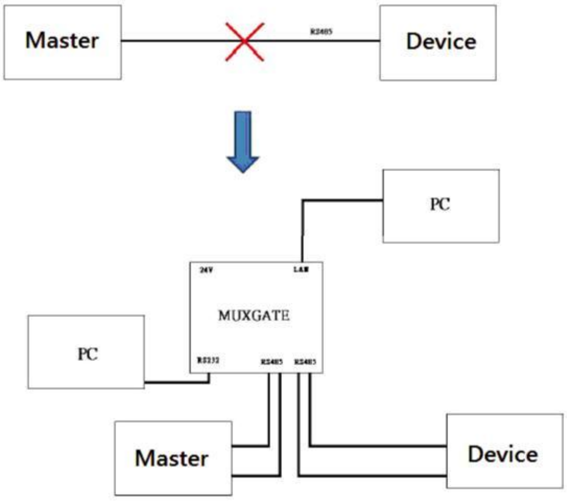


Figure 6: M3280 wiring schematic diagram.

The Elnet LT Energy & Power Multimeter smart meter [4] is a multimeter that can display the voltage, current, power factor, frequency, neutral current, and energy consumption on a panel, as shown in Figure 7. This equipment is designed to be combined with the management system in the equipment. Another function calculates the harmonic number, where the user can decide whether or not to monitor the harmonic number or improve the harmonics at will, in order to upgrade the quality of renewable energy power supply.

Figure 7: Elnet LT electric meter display interface.

3. Data transmission process

The PV system of this laboratory is mounted in the north, middle, and south buildings. The poly silicon power generation module, inverter, sunshine recorder, module temperature meter, and Elnet smart meter are mounted in each building. The equipments are connected via the RS485 communication interface, and the metering converter of each building converts the signal from RS485 into Ethernet. Finally, the monitoring data are sent to the server of this laboratory. The data of the three buildings are stored in the solar energy Cloud management system. Figure 8 shows the structure of data transmission.

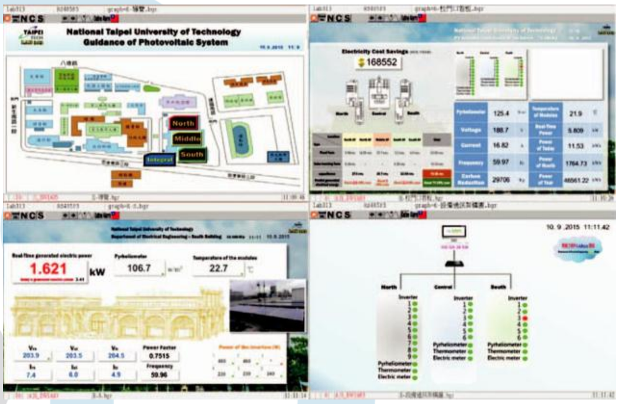


Figure 8: Structure of data transmission.

4. System monitoring and management

The monitor screen designed for this system is as shown in Figure 9, which provides remote management and real-time monitoring. While general visitors can browse the real-time power generation situations of different network devices, only the administrator can log into the management functions of the power generation trend map, failure warnings, and electricity generation reports.

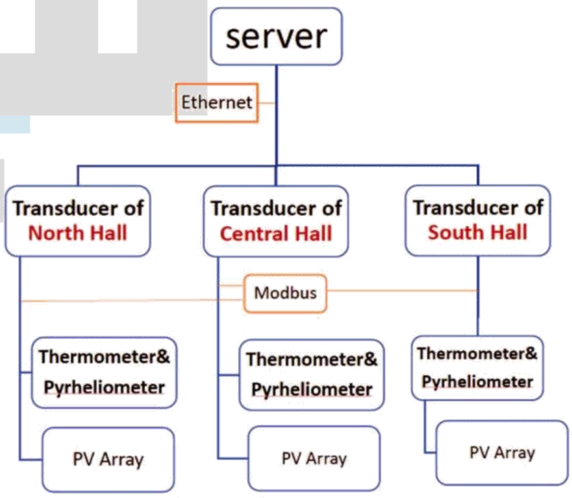


Figure 9: Solar energy remote monitoring system menu.

V. CASE ANALYSIS OF A SOLAR ENERGY CLOUD MANAGEMENT SYSTEM

1. Comparison between the horizontal one-axis sun tracking module and fixed module

This system is constructed according to the specifications and studies of the Bureau of Energy, Ministry of Economic Affairs and IEEE [6-7], the installed capacity is 70.38 kWp. The annual electricity generation is estimated at 70 thousand KWh. The installed capacity of the fixed module is 53.82KWp; the installed capacity of the sun tracking module is 16.56KWp.

When the system was completed, the electricity generation did not reach the expectation of previous years due to various equipment failures, cleaning of the solar power generation module, or inverter conversion efficiency. According to the comparison between the fixed module and sun tracking module, the electricity generation of the sun tracking module is 1.25 times that of the fixed type in summer, thus, the effectiveness of the sun tracking system is implemented.
However, the electricity generation of the sun tracking module is lower than that of the fixed module in autumn. While the construction cost of the sun tracking module is much higher than that of the fixed type, its power generation cannot reach the expected effectiveness of one hundred percent, and the reasons are discussed, as follows.

2. The elevation angle and the position angle of the sun

The elevation angle (also known as the altitude angle) refers to the measuring point at 0 on the horizontal plane, the maximum elevation angle of the sun, and the sun on the horizontal plane is defined as 0; it is 90 straight above the measuring point, the elevation angle of the sun varies with time, and it is related to the latitude of the measuring point [8].The position angle describes the relative position of the sun to the measuring point. If the true north of the measuring point is defined as 0, then true east is 90, and true south and true west are 180 and 270, respectively. One counter clockwise revolution is just 0°-360°, and the angle resulted from the rotation of the measuring point is defined as the sun azimuth[9]. The position angle and the elevation angle of the sun are as shown in Figure 10.

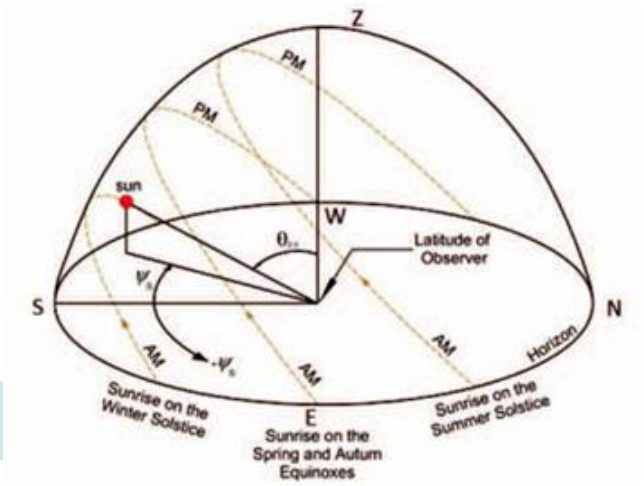


Figure 10: The position angle and the elevation angle of the sun.

3. Analysis of angle between solar module and solar angle of incidence

Figure 11 describes the angle relationship between the solar module and solar angle of incidence. There are two given conditions before analysis: the inclination of the fixed module is 23.5 ; the inclination of the sun tracking module is 65 in the east and west directions, respectively (24 hours of a day are divided by 360°, it shall rotate 1° every 4 minutes), as based on the astronomical calendar. The following experiment calculates the result of noon, where the evaluation period is 11:30-12:30, and difference angle is expressed as Eq. (1). According to the solar angle of the incidence and the solar module panel angle, when the solar angle of the incidence is at 90° to the module panel, the module exports the maximum power.

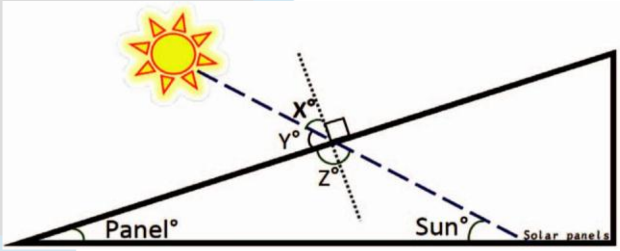


Figure 11. Angle relationship between the solar module and solar angle.

4. Power benefits of fixed module and one-axis sun tracking module

The average effective sunshine duration is 2.5 hours in Taipei, where the sunshine duration and amount reach their maximum in summer and their minimum in winter. The daily main generating duration is 10:00-15:00, and the maximum sunshine amount occurs at noon [10]. This experiment takes one hour of noon as the sample, and Table I lists the angle differences in this period. Table II and Figure 12 compare the electricity generation of the fixed and sun tracking modules.

TABLE I. ANGULAR DIFFERENCE BETWEEN SOLAR TRACKING SYSTEM AND FIXED SYSTEM ON FEBRUARY 25TH, 2015

Angular difference (X)	11:24	11:32	11:40	11:48	11:56
elevation angle	45°	45°	45°	46°	46°
position angle	166°	169°	171°	174°	177°
Solar tracking system	36°	38°	40°	41°	43°
Fixed System	21.5°	21.5°	21.5°	20.5°	20.5°
Angular difference(X)	12:04	12:12	12:20	12:28	12:36
elevation angle	46°	46°	46°	46°	45°
position angle	179°	182°	185°	187°	190°
Solar tracking system	43°	41°	39°	37°	36°
Fixed System	20.5°	20.5°	20.5°	20.5°	21.5°

TABLE II. THE COMPARISON OF THE ELECTRICITY GENERATION OF THE TWO SYSTEMS.

Season	Tracking systems(W)	Fixed systems(W)	Power ratio
Summe(the end of July)	1236.56	990.64	1.25
Summe(the end of August)	1232.65	1071.73	1.15
Autumn(the end of October)	969.67	1010.51	0.96
Autumn(the end of November)	741.97	780.09	0.95
Winter(the end of January)	619.44	617.53	1.003
Winter(the end of February)	968.95	943.43	1.03
Notes : The power ratio is(Tracking systems(W) / Fixed systems(W))			

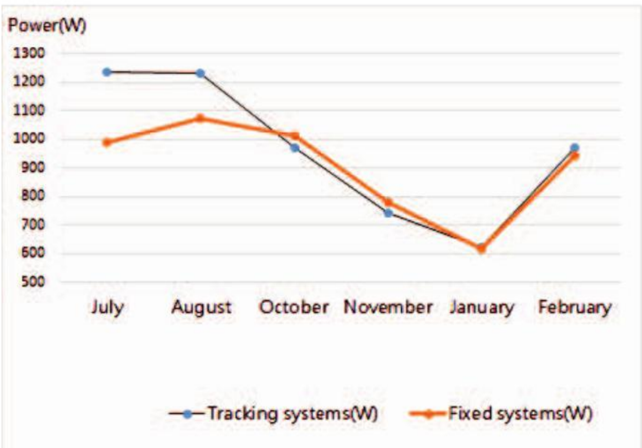


Figure12: The comparison of the electricity generation of the two systems.

The analysis result in Figure 12 indicates that, generally speaking, as the sun tracking module can track the solar angle, the electricity generation of the one-axis sun tracking module is higher than that of the fixed type, thus, the time of receiving direct sunlight is longer. As the number of days of direct sunlight decreases in autumn, the fixed module at 23.5° southwards does not perform better than the southward oblique sun tracking module.

To solve the above problem, the one-axis sun tracking system shall be tilted to a southward angle, where the preferred angle is 23.5 , in order that the originally east-west rotating sun tracking system better meets the 90 solar angle of the incidence.

CONCLUSIONS

To maintain good operation of the PV generation system, in addition to Cloud monitoring, equipment maintenance is an important engineering factor, and none of the parts shall be neglected. At present, there are serious problems in the management of many solar power systems in Taiwan. As green energy power generation cannot steadily supply power in the long-term, and field staffs sometimes have no related expertise, it is difficult to find problems immediately, thus, equipment maintenance and replacement results in considerable additional costs. The Cloud management system, as constructed in this study, can implement comprehensive monitoring and management, find problems instantly, and propose solutions, in order to maintain system operation and enhance overall effectiveness.

The findings show that, in order to completely perform an effective sun tracking module, the horizontal one-axis sun tracking module (as this field, 0 elevation angle southwards) shall be changed to an oblique one-axis sun tracking module tilted 23.5 southward, in order to match the solar angle of incidences in Taiwan, and electricity generation in any season can be better than the fixed module. In a complete Cloud management system, it is very important to guarantee the data transmission and storage of mass data, thus, the performance of a server becomes the key factor, as it requires sufficient stability and reliability, a powerful CPU for processing complex operations, a short response time, and appropriate data storage and distribution to avoid loss.

This study constructs a solar energy Cloud management system, which is aimed at "equipment monitoring, system management, and data analysis". In addition to the PV system of this laboratory (70.38kWp), in the future, the systems of other fields will be imported, and the solar power systems of various footholds are imported into this administration platform in order to increase the number of samples for data analysis. For users, green energy management is no longer a problem for effective monitoring. As green energy becomes popularized, a practical reference is provided for solar power system designers and constructors.

REFERENCES

[1] “Million Rooftop PVs,” Industrial Technology Research Institute ,Taiwan ,2015.

[2] Richard M. Swanson, “A VISION FOR CRYSTALLINE SILICON SOLAR CELLS,” SunPower Corporation, Sunnyvale, CA 94085 USA.

[3] Green M.A, Zhao Jianhua , Wang Aihua,Wenham S.R, Very high efficiency silicon solar cells-science and technology, IEEE Electron Devices Society, Oct 1999.

[4] “ElNet LT Energy & Power analyzer,” Feniks Pro, Slovenia EU,2000.

[5] Guarese G.B.M., Sieben F.G., Webber T., Dillenburg M.R., Marcon, C., “Exploiting Modbus Protocol in Wired and Wireless Multilevel Communication Architecture,”IEEE Computing System Engineering (SBESC) ,pp.13-18, November,2012.

[6] IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems ,2003.

[7] Nowlan M.J., Murach J.M., Sutherland S.F.;Miller, Hogan S.J, “Development of automated photovoltaic module manufacturing processes”,IEEE Photovoltaic Specialists Conference, pp.414-417, May 2002.

[8] Christiana Honsberg and Stuart Bowden, ”Elevation Angle,”PVCDROM, http://www.pveducation.org/pvcdrom.

[9] Christiana Honsberg and Stuart Bowden, ”The Sun's Position,”PVCDROM, http://www.pveducation.org/pvcdrom.

[10] George A, “Analytical and experimental analysis of optimal tilt angle of solar photovoltaic systems,” Dept. of Electr. Eng., Amal Jyothi Coll. of Eng., Kanjirapally, India ,pp.234–239,2012.