Analysis of development of a solar tracker engineering essay

Engineering

There is a range of attractive solar tracking systems of moderate size. In this project is needed to survey this field and to develop a two degrees-of-freedom solar tracker. New construction and testing phases can then proceed. The present project deals with the electric power that is produced using solar panel. More precisely, it is presented the procedure of converting solar energy into electrical energy, the components which comprise the whole system as well as the study if such an investment is beneficial. To achieve a better view for the subject will seek alternative ways designs of a two degrees-of-freedom solar tracker. These systems are consisted from mechanical and electrical components which are connected each other with appropriate way and produce electricity from the solar energy of the sun. Moreover, a technical analysis will be made, evaluating the whole installation and the advantages and disadvantages of the solar tracker. After the design and fabrication of the new type of the solar track system, some measurements are made for its characterization. The data and the results which will be collected will be studied and analyzed, leading us to considerable conclusions. 1. 2 NOVELTYThere are two basic solar tracker types which exist and are: 1) The one degree of freedom solar tracker and 2) The two degree of freedom solar tracker which is proven that are more efficient. These two types are differing in design and operation. To make certain highest energy collection efficiency, it is planned that a sun tracking system be developed to continuously align the collector surface normal with the instantaneous solar radius at all the duration of operation. This project will examine a two degree of freedom solar tracker using Azimuth/Zenith axes and then to improve their design. The novelty is to improve the performance of a two degree of freedom solar tracker. This means that the solar tracking system can utilizes the sun more and therefore to produce more electrical power. 1. 3 AIMS OF THE PROJECTThe aim of this project is to design and test a two degree of freedom solar tracker of moderate size and to analyze their performance and characteristics. In order to design a two degree of freedom solar tracker, will focus our research at technical parameters. The objective is to design and construct an efficient with low cost, practical solar tracker. 1. 4 THE MAIN WORK-PACKAGESSun-tracking device is one of the key components in solar energy collecting systems, including the thermal and photovoltaic systems. The project is to improve the design and control of a solar tracker (with two solar panels) in the Robotics Lab in the department of mechanical engineering in order to improve its net efficiency. The tasks mainly include the measurement of net efficiency of the tracker, control, the necessary mechanical design, simulation, fabrication, and improvement of control. Solidworks (or Solid Edge) and Matlab/Simulink (or Labview) is to be used in this project. The main objectives of this project are: Design a dual axis solar tracker: Find an alternative design of a dual axis solar tracker. Fabricate the mechanical and electrical components. Find the appropriate dimensions for each component. Indicate the material that should be used. Connect all the mechanical and electrical parts of the dual axis solar tracker. To build a microcontroller unit that actively tracks the sun to maximum solar panel output. To build accurate sensors to locate the sun's position and aligning the array using the microprocessor so that all sun rays are normal to the array surface. Calculate initially the mechanical and electrical power. Create a Mechanical design using Sold Edge software. Control the solar tracker using Labview software in the Robotics Lab. Testing a dual axis solar tracker: Calculate the net power output. Placing the unit in the workshop and taking daily measurements of the power output. Placing the unit outdoor and taking daily measurements of the power output (with different weather conditions). Observation the balance of the system at indoor and outdoor conditions. Measuring the effectiveness of the unit. 1. 5 THE EXPECTED OUTCOMESWith experiments in the workshop and outdoor of the dual axis solar tracker, the results of the net power output will be summarized and then analyzed. More analytically, the dual axis solar tracker will be tested on the different solar radiation till the solar panels produce higher power. 1. 6 THE TECHNICAL RISKS ANTICIPATEDThe probable technical risks which can be found in the lab at the duration of this project are: The construction of each Electrical/Mechanical component. The connection of each component. The material may not be the appropriate. The operation maybe not efficient. 1. 7 THE RESOURCES NEEDEDThe design of the dual axis solar tracker requires the appropriate dimensions and type for each part of the dynamic system. With the use of Solid Edge software will design each component separately. The construction of the dual axis solar tracker requires many materials as estimated below: Base (aluminium). Two monocristaline solar panels. Two servo motors. Microcontroller unit. 9 Photocells. WiresAll the Mechanical and Electrical components can be found at the workshops of each department or can be bought from stores. The cost is estimated around 100 pounds which depends of the materials and the quality. Also, the testing requires the use of robotic laboratory in order to take the appropriate measurements. 1. 8

THE BENEFICIARIES OF THE WORKThe opinions and the conclusions that are contained in this project express the writer and it should not be interpreted that they represent the official places of the Heriot-Watt University. Beneficiary of this work is the supervisor Dr. Xianwen Kong and the MSc student Georgios Siapalidis. The project is addressed for educational purposes at Heriot-Watt University and for the use to supply electricity for commercial or private uses. 1. 9 ABSTRACTAs the demand for energy worldwide increases, utilizing renewable resources has become an important way to combat the impending energy crisis and to reduce carbon emissions. Development of a low cost a two degree of freedom solar tracker can increase the efficiency of a solar collector in an economically beneficial way. This paper focuses on the development of a solar tracker using a microcontroller and nine photocells with two servo motors which track the solar panels. One configuration for the solar system was considered, the dual axis solar tracker due to its effectiveness. To analyze the control system for the dual axis solar tracker, experiments were set up for the system to track the sun on a cloudy day and a sunny day. This model proved to be a successful prototype for a low cost solar tracker, since it satisfyingly follows the sun on a sunny day. After the report of the basic characteristics of the system, is presented the operation of each component. It becomes a critical analysis of the advantages and disadvantages. Afterwards, every component of the dual axis solar tracker is described analytically and thoroughly. The basic steps of the design and testing of a dual axis solar tracker is presented with emphasis and becomes discussion leading us to considerable conclusions.

2. LITERATURE REVIEW

1. INTRODUCTION

The need for development of the modern world has imposed an everincreasing energy demand. The gradual depletion of fossil fuels reserves combined with the irreversible environmental consequences of their widespread use resulted in an effort for the rational use of fossil fuels and in energy production from environmentally friendly technologies. One of these is the exploitation of solar energy, a photovoltaic phenomenon through which the solar energy is converted directly into electricity. Nowadays, it is commonly acceptable that environmental benefits may come from the energetic solar systems (photovoltaic systems, solar thermal) in contrast with conventional sources of energy that are not the same environmentally friendly. Energetic solar systems are necessary for the sustainable development of human activities. The use of fossil fuels causes serious problems in environment as it increases the pollution of air with the production of various quantities of carbon dioxide emissions and in general that leads to climate changes of earth. The electrical production with the PV applications helps in reducing significant amounts of CO_2 emissions to the air and also it constrains the power transmission and distribution lines losses. The use of photovoltaic (P/V) systems for the production of electric energy is increasing and it evolves continuously. It becomes a technology widely widespread in all Europe. Photovoltaic (P/V) systems are discerned in grid-connected systems, which are connected to the network of electric power, and in autonomously systems, where accumulators (batteries) are used.

2. SOLAR RADIATION

The earth rotates in 24 hours about its own axis, which defines the points of the north and south poles N and S respectively.¶ Latitude is defined positive for points north of the equator, negative south of the equator. Longitude is measured positive eastwards from Greenwich. The vertical north-south plane through P is the local meridional plane. More analytically we can see the Figure 2. 1 that shows the rotation of the Earth and illustrate the following points [1]:¶The axis of the poles is normal to the earth's equatorial plane. C is the centre of the Earth. The point P on the Earth's surface is determined by its latitude φ and longitude ψ. E and G are the points on the equator having the same longitude as P and Greenwich respectively. Figure 2. 1 Definition sketch for latitude φ and longitude ψ. [1]The hour angle ω at P is the angle through which the Earth has rotated since solar noon. Since the Earth rotates at /24h=, the hour angle is given by:(2. 1)The Earth orbits the Sun once per year, whilst the direction of its axis remains fixed in space, at an angle δ0 = 23. 45° away from the normal to the plane of revolution. The angle between the Sun's direction and the equatorial plane is called the declination δ, relating to seasonal changes. Circles of latitude 0°, ±23. 5°, ±66. 5° are shown in the Figure 2. 2. Note how the declination φ varies through the year, equalling extremes at the two solstices and zero when the midday Sun is overhead at the equator for the two equinoxes [1]. Fig 2. 2 The Earth, as seen from a point further along its orbit. [1]δ varies smoothly from +δ0 = +23. 45° at midsummer in the northern hemisphere, to δ0 = -23. 45° at northern midwinter. Analytically,(2. 2)where n is the day in the year (n = 1 on 1 January). The error for a leap year is insignificant in practice.

2. 1 DEFINITION OF THE SOLAR BEAM

The scattered radiation reaching the earth's surface and coming from all parts of the sky apart from the direct sun is called diffuse radiation. For the tilted surface of the collector represented in Figure 2. 3, define [1]: Figure 2. 3 Angles between sun and collector. [1]For the collector surface: Slope β (The angle between the plane surface in question and the horizontal). Surface azimuth angle γ (Projected on the horizontal plane, γ is the angle between the normal to the surface and the local longitude meridian). Zenith angle Θz (Angle of incidence θ, slope β and azimuth angle γ for a tilted surface). Angle of incidence θ (The angle between solar beam and surface normal). For the solar beam: Zenith angle θz (The angle between the solar beam and the vertical). Solar altitude αs (= 90°−θz) (The complement to the (solar) zenith angle and the angle of solar beam to the horizontal. Azimuth angle γs (Projected on the horizontal plane, the angle between the solar beam and the longitude meridian. Hour angle ω (as in (2. 1)) (The angle Earth has rotated since solar noon when γs = 0 in the northern hemisphere). 3. THE PROCESS OF DESIGNING A PV SYSTEMThere are many different types of PV systems available with different features and characteristics. The basic principles in the different types of the PV systems are the following: Stand-alone DC system (PV array, batteries, charge controller, DC loads). Stand-alone DC/AC system (PV array, batteries, charge controller, DC/AC inverter, DC/AC loads). Hybrid system (PV array, batteries, charge controller, battery controller, generator, system controller, DC/AC inverter, DC/AC loads). Grid-connected system (PC array, system controller, DC/AC inverter, AC loads, network). The main parts of an autonomous photovoltaic system to cover the electrical demand of the house appliances are highlighted to the following Figure 3. 1: Figure 3. 1 Stand-Alone DC/AC system. [13]The PV system will include some devices as PV array, control panel, charge controller and batteries. The different parts of the system will be described below:

PV array

The PV array is constituted from many PV cells that are connected between them. PV cell is the elementary unit of PV system because there is converting the solar energy into electric energy. A PV array is made up of PV modules, which are environmentally-sealed collections of PV cells and these devices converting the sunlight into electricity.

Inverter (DC/AC)

This is the device that takes the DC power from the PV array and converts it into standard AC power used by the house appliances. Inverters are electronic devices that are used in the grid-connected systems but also in autonomous systems with recharged batteries.

Battery

Autonomous PV systems require storage of energy in order to have the possibility of functioning also in periods without or with few solar radiations, as at the duration of night or at the duration of shading.¶ However the experience has shown that in an autonomous PV system the battery¶ is the most impossible point, as the duration of life is generally much smaller compare¶compareefe all the other units of system. ¶Formally the battery in an autonomous PV system is sizing to ensure that provided the solar radiation does not suffice, the loads needs, they can cover for at least 3-4 days.¶ The result of sizing of this is the percentage of daily discharge battery of PV system it is roughly 25% with 30% of the theoretical capacity [3, 4].¶

Charge controller

Its function consists on protecting the system of accumulation and avoiding extreme behaviour cases that could injure the batteries. 3. 1 FACTORS AFFECTING OUTPUTThere are many factors which affect the output electrical generation of the PV cells. More analytically these factors are:

Standard Test Conditions

Solar modules produce DC electricity. The DC output of solar modules is rated by manufacturers under Standard Test Conditions (STC). These conditions are easily recreated in a factory, and allow for consistent comparisons of products, but need to be modified to estimate output under common outdoor operating conditions.

Temperature

Module output power reduces as module temperature increases. When operating on a roof, a solar module will heat up substantially, reaching inner temperatures of 50-75 °C. For crystalline modules, a typical temperature reduction factor recommended is 89% [2].

Dirt and dust

Dirt and dust can accumulate on the solar module surface, blocking some of the sunlight and reducing output. A typical annual dust reduction factor to use is 93% [2].

Mismatch and wiring losses

The maximum power output of the total PV array is always less than the sum of the maximum output of the individual modules. This difference is a result of slight inconsistencies in performance from one module to the next and is called module mismatch and amounts to at least a 2% loss in system power. A reasonable reduction factor for these losses is 95% [2].

DC to AC conversion losses

The DC power generated by the solar module must be converted into common household ac power using an inverter. Some power is lost in the conversion process, and there are additional losses in the wires from the rooftop array down to the inverter and out to the house panel. Actual field conditions usually result in overall DC-to-AC conversion efficiencies of about 88-92%, with 90% or 0. 90 a reasonable compromise [2]. 3. 2 MOUNTING OF PV MODULESThe sitting of the PV modules should be having the following characteristics: Resistance in air. Low cost. Reject of shading. Easy approach so that is possible to cleaning the PV units. The manufacture of PV should allocate height so the units not danger from the vegetation or from stones, but simultaneously to be possible the easy cleaning.¶ Because the PV units are very expensive it should be well mounted in order to be difficult their theft.¶ Finally the units should have a suitable distance between them and from the hedge for the avoiding phenomena of shadings. The construction sitting of PV arrays are separate in three categories: Constant structure. Structures with the possibility of rotation in axis. Structures with the possibility of rotation in two axes. The constant structures are the simplest. The modules are placed in concrete orientation and bent and they remain thus for all the duration of their operation. They have the lowest cost but cause their constant mounting have also the smaller production of energy. 4. DESIGN OF THE PV SYSTEMThere are many manufactures at the world market which design PV modules and solar cells [13]. The most common will be described in the table 6. 1: Table 6. 1 Summary of Current Photovoltaic Technology. [13]As can see in the table above there are four different cell types with different characteristics. The advantages and disadvantages, the efficiency of the solar cells and the cost are very important parameters for the choice the appropriate PV modules from the manufactures design. More analytically the Table 6. 2 shows the features of the different solar modules:

Solar module

Efficiency

Lifetime

Price

Power/

Area

Monocrystalline10 - 13%25 years 90% rated power 30 years 80% rated power typicalhighhighPolycrystalline9 - 13%10 years 90% rated power 25 years 80% rated power typicalmoderatemoderateAmorphous6 - 8%10 yearslowlowTable 6. 2 Monocrystalline, polycristalline and amorphous modules features. [14]The choice of the appropriate PV module depends on many electrical and mechanical parameters as the peak power, the material, the dimensions, the weight, the temperature, the voltage, the current e. g. After research from different types and manufactures the two monocrystaline solar panel characteristics for the prototype is mentioned in table 6. 3:

Output Power (W)

10Watts

Dimension (mm)

286 x 406 x 25

Weight (Kg)

1. 5

Working Voltage (V)

16. 8

Working Current IUP (A)

0. 59

Open Voltage VOL (V)

21

Short Circuit Current ISC (A)

0. 66

SLA battery Voltage (V)

12Table 6. 3 Characteristics of the PV modules. In order to reduce the costs, two appropriate servo motors have been taken from an older project and their characteristics is mentioned in the table 6. 4:

Operating Voltage:

4. 8-6. 0 V

Stall Torque (4. 8V):

3. 3Kg. cm

Stall Torque (6. 0V):

4. 1Kg. cm

Current Drain (4. 8V):

8mA/idle and 150mA no load operating

Current Drain (6. 0V):

8. 8mA/idle and 180mA no load operationTable 6. 4 Characteristics of the Servo motors HS-425BB

Solar Systems

These systems exploit the solar energy are developed and continuously evolving in order to increase their performance while reduce costs and losses. These systems can be divided in the following categories: 1) Passive solar systems. 2) Photovoltaics. 3) Active solar systems. Passive solar systemsPassive solar systems are components of a building through which use the direct or indirect solar energy for heating or air conditioning purposes. Passive solar systems absorb solar energy either directly (direct gain systems), or indirectly indirect gain systems), or by isolated systems (isolated gain systems). (apo anaptyksh)In the case of direct absorption, the solar radiation penetrates the building through large glass windows. The heat stored in interiors, such as in the floors and interior walls. In the indirect absorption, the heat stored in the walls located between the sun and inside the building. In contrast, the passive solar system absorbs solar radiation indirectly the flow of heat inside the building and is more effectively. The main storage component in these systems is water and the facilities are located on the exterior walls or roofs of buildings. In the third case, solar energy is stored in a third body and then goes inside the building. The third body is usually outside of the building. PhotovoltaicsTo 1839, French physicist Edmund Becquerel observed that the solar radiation changes the properties of certain materials. More specifically, it found that these materials, when llluminated, can produce electricity through the photovoltaic effect. (apo anaptyksh)A photovoltaic module consists of a piece of semiconductor material, on which two electrodes are placed the edges with which the generated electricity. This is the main component of a photovoltaic system (Figure 1. 3) as called the system exploits solar radiation for electricity generation [5]. The yields of the most common solar cell (silicon) ranging from 6-10% for amorphous silicon elements and reach up to 20-24% for most monocrystalline silicon expensive items commonly used in space applications. Here are the main advantages of using photovoltaics. Benefits: It is environmentally friendly. Have quiet operation. Has reliability and long life. They have zero maintenance costs. Does not affect the aesthetic environment. There is a possibility to expand to cover increased energy needs. They require minimal maintenance. Convert solar energy directly into electricity. The energy produced can be stored in batteries. Can be combined with other energy sources, eg a wind farm. They can cover the production of energy in inaccessible places (beacons, mobile phone antennas, etc.). The high cost of manufacturing solar cells is main disadvantage. Active solar systemsIn contrast to photovoltaic systems that use solar radiation directly to electricity, active solar systems use sunlight to produce heat used to generate electricity or to heat water or air, depending on the species. Active solar systems are divided into two major categories: solar panels and composite solar collectors. The principle of flat solar collectors based on absorption of solar radiation and heat efficiency in the middle transport. It could be air or water. Characteristic of flat solar panels is that take advantage of the direct and diffuse radiation and do not concentrate sunlight using reflectors. In the composite panels used in solar reflectors Aggregate surfaces or lenses to collect solar radiation on a receiver. The receiver may be located at a point (aggregated collectors spot focus) or a line (pivot Collectors linear focus). The panels are aggregated principal component of solar thermal power energy. In these systems, the receivers of centralized collector convert solar radiation into heat which is used to production of superheated steam. Then the steam is transferred through special pipe in a steam generator to the opening of which is produced electricity. (apo anaptyksh)7. ECONOMIC ASSESSMENTThe techno economic studies of the photovoltaic systems include many parameters. In our case we estimated the main photovoltaic equipment as the PV panels, batteries, inverters, cables, switches, postage and mounting elements. More analytically there are initial and annual costs which comprise: Initial costs including: Feasibility study which comprises of the site investigation and preliminary design of the site. Development which constitutes the permits and approvals of a project management. Design of PV system. Photovoltaic system equipment (PV modules, inverters, batteries). Electrical equipment and design. Postage. Mechanical study of location. Annual costs including: Operation and maintenance (taxes and insurance). Contingencies.

7. Conclusions

This project focuses of controlling two sun tracking arrays with an embedded microprocessor unit. Specifically, it will demonstrates a working software solution for maximizing solar cell output by positioning a solar array at the point of maximum light intensity. This project presents a method of searching for and tracking the sun. The established prototype of solar tracking system was designed with two degrees of freedom so that it is able to track the sun through Azimuth and Zenith. It contains two major assemblies: Zenith-tracking top and Azimuth-tracking base. The parts for each assembly were rapid prototyped and can be developed in order to improve their net efficiency. The Azimuth assembly consists of a worm gear drive and the Zenith assembly contains a lead screw mechanism. An autonomous photovoltaic system can cover the electrical demand of the house appliances for future dwellings. It then can became with estimations for the consumption (electrical appliances of the house), for the solar data of the region, the way the PV panels be mounted, the choice of the parts of the system and how it can be connected each other.