Proposed sun tracking system

Abstract

Introduction

The basic design of a solar thermal power generation system is as shown in the figure. In such a system, the major components are the solar energy concentrator, sterling engine and the dynamo (alternator) unit.

A parabolic dish reflector acts as the concentrator in this system.

To achieve a good performance from a solar thermal conversion engine, it should be exactly mounted on a place where maximum heat transfer is possible.

It is the center or the focal point of the parabolic reflector surface.

Then only the engine receives the maximum amount of solar thermal energy, which will be converted into kinetic energy and then to electricity.

There are two possible configurations for the placement of the sterling engine depend on the surface type of the reflector.

They are known as prime focus configuration and the offset focus configuration.

Because of the position of the sun changes according to the rotation of earth, the parabolic surface has to be focused to the direction of the sun at all the times.

The proposed solar tracking system consists of hardware and software to achieve following capabilities

Localization

The position of the Sun in a given time can be calculated using mathematical equations based on the time, location, altitude and few other factors. To perform such a calculation, the exact location of the device should be known. Since this device is not mounted on a mobile configuration, it is not hard to find the exact location with help of a map or a GPS device after install in the field. But it is more convenient to use an embedded GPS receiver with this system. This will eliminate the requirement of initial setup and it also capable of providing the precise UT timestamp based on the synchronized satellite clocks. It makes this device a location independent and time independent high precision solar tracking mechanism.

NREL Solar position algorithm (SPA)

Several methods and algorithms to calculate the position of the sun has been published in the literature of the solar research, but most of them were not precise enough because their uncertainties have been greater than ± 0. 01. Reda and Andreas implemented a new algorithm which is capable of estimate the position of the sun with uncertainties of ±0. 0003 and well known as solar position algorithm (SPA) by National Renewable Energy Laboratory (NREL).

Feedback loop mechanism MPU 9250 IMU

In this solar tracking system, orientation of the reflector surface is precisely controlled and maintained by a closed loop control system. Therefore this system should consist of a feedback mechanism to obtain the current orientation of the reflector as the feedback input of the control loop. There are several methods to fulfil this requirement. For example, a read reckoning based method such as a rotary encoder with a known reference point can be used per each axis. But since it increases the mechanical complexity of the system there is a very higher chance of causing mechanical failures and sensor issues. To eliminate this problems while keeping the accuracy in a higher level, a micro electro mechanical systems (MEMS) [] based implementation is suggested. Among the advantages of this kind of devices less power usage, high accuracy, fast response, less complexity and the minimal space requirement are mostly highlighted in this application.

Inertia Measuring Units (IMU) are very popular in the fields of mobile devices, game controllers, drone flight control systems and self-balancing toys because they provide the angular position coordinates (Yaw Pitch and Roll) in a very higher sample rates. They are also accurate enough to balance and guide a wireless controlled drone in a very high level of accuracy even in the industrial electromagnetic noise and interference. This devices are normally consist of a gyroscope, and accelerometer and a magnetic compass. To ensure the maximum accuracy in all directions, it is recommended to use 3 axis devices. Theoretically we can say that with the only help of a gyroscope, it is possible to calculate the angular orientation in Euler coordinates, but the problem of using a single device is it may generate very much of error when continuously using in long time periods. It is commonly known as the gyroscope drift. This can be compensated by using a secondary device which corrects the drift and it is the accelerometer. This combined sensor based approach is commonly described as sensor fusion. There are several sensor fusion algorithms available in the industry such as Karlmann filter and the complementary filter. In this research, Karlmann filter based algorithm has been used.

With the both accelerometer and the gyroscope sensors, now we can accurately calculate the Euler angles of the reflector when the IMU is placed near the focus point of the Parabola. The offset values can be preconfigured to match the exact difference between the sensor position and the focal point. But we need one more reference point to convert this coordinates into altitude and azimuth vectors. It is the north direction and can use a magnetic compass to obtain this parameter. But it also need a very much higher level of calibrations due to the magnetic field variations depend on the situations and the locations. In this research, the nine axis MPU 9250 has used. It is an integrated chip with 3 axis MEMS gyroscope, 3 axis MEMS accelerometer and a 3 axis magnetic compass. It has a 16bit RAW data outputs on each axis and therefore a very high accuracy is obtained.