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Heliostats Automation System for a Solar Power Tower Plant's Efficiency Increment

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***Abstract*—** In this paper a System for the automatic positioning of the heliostats of the Solar Power Tower plant is presented a cloud detection system and a sun position algorithm will compute the exact position of the Sun, and the clouds will be detected next to the sun in order to preserve the integrity of the power tower's system. The main purpose of this system is to achieve a maximum efficiency by changing the positions of the heliostat to away from the sun, when the clouds are about to cover the sun. In this way we can maintain the integrity of the system and to avoid damaging of the central receiver. The data that are used in the source code for the computation of the outputs from the given input parameters are also discussed. The system is successfully shock free and more efficient.

***Keywords*—** Power tower plant, Sun position, Cloud detection, Central receiver, Heliostats

I. INTRODUCTION

Solar energy is a renewable form of energy and only a onetime cost is required for the life time process of the system, The Power towers are the solar furnaces which are using a central tower to receive the focused sun light on the central receiver at the top of the tower. Molten salts are present in the tower which absorbs the solar heat and thus running the thermal generators to produce a clean and a good amount of power. The molten salts used in the power towers are good heat absorbers and have a high amount of heat capacity, it contain 40% of Potassium nitrate and 60% of Sodium nitrate. The power towers have a capability of generating electricity, even when the sun is not shining and the heliostats are not focusing the sun light on the central receiver, which is at the top of the tower.

We have mainly two issues under this discussion for the power towers, one is that, all the day the sun is not incident directly on the static heliostats and the other one is that, the central receiver has reached the temperature up to about 800 degree centigrade by the continuous focusing of sunlight by heliostats on the central receiver, so when suddenly a cloud covers the sun so the central receiver suffers a thermal stress and when this phenomenon occurs several times so the central receiver gets damage which is a huge loss [1].

We have to make the heliostats mobile so that it should trace the sun automatically all the day by knowing the exact positions of the sun and so that it should change its position away from the incident sunlight when the cloud is near to the sun so that to avoid the thermal shocks of the central receiver, this automatic system will increase the efficiency of the power towers dramatically.

This paper is organized as follows: Section 2 is dedicated to present an algorithm which will show us the exact position and location of the sun at any instance of time. Section 3 is there to present a method to get a super pixel segmented image of the cloud. Section 4 contains conclusions. Below is the positioning system diagram shown which clarify the main idea of our work. We have two inputs to the master control system, one is the result of the digital image processing which gives us the super pixel segmented image as a result and the other one is the sun position algorithmic result which gives us some outputs and those are also inputs to the master control system.that follow.

As shown in the positioning system diagram, first of all we have a method of super pixel segmentation which include some features extraction through digital image processing techniques from the original image of the scene, the image is captured with infrared camera and first image patching features are extracted, then RGB, then image threshold, then grayscale, then edges are detected, then after image segmentation we get the super pixel segmented image which is our output through digital image processing and that super pixel segmented image is given as an input to the master control system. The other inputs to the master control system are the sun position parameters which are showing us the exact position and location of the sun at any particular instant of time.

The outputs which the sun position algorithm will give us are following:

Azimuth angle

Zenith angle

Sun rise time

Sun set time

Incident angle

Julian day

Earth heliocentric longitude

Earth heliocentric latitude

Earth radius vector

Observer hour angle

Nutation longitude

Nutation obliquity

Ecliptic true obliquity

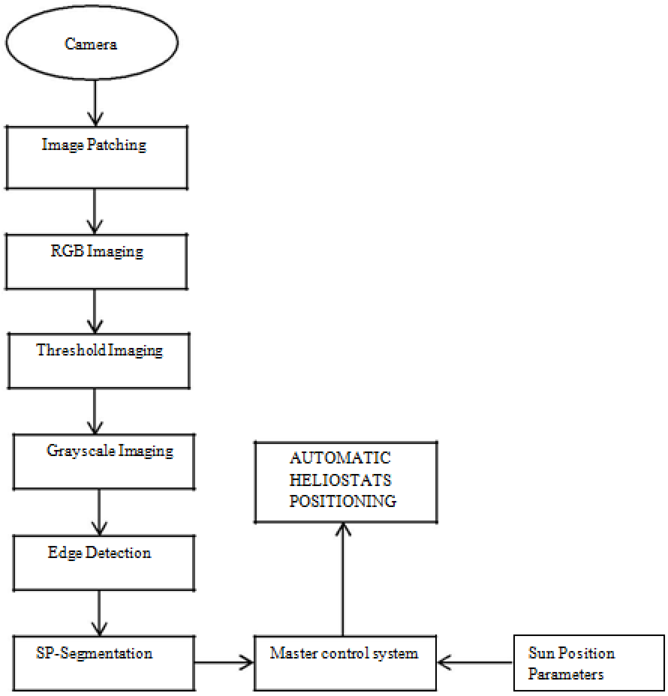

Figure 1. Positioning System Diagram

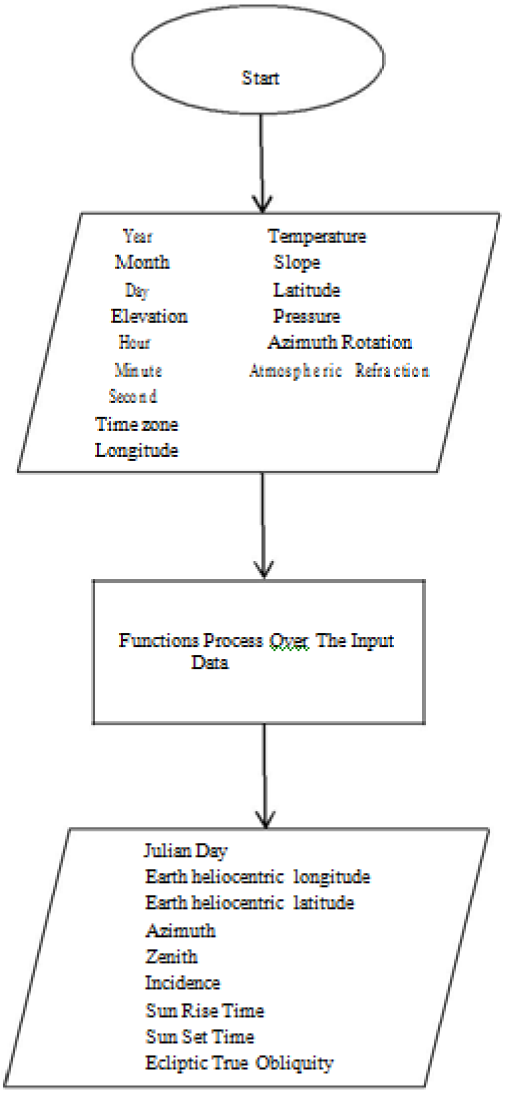

Figure 2. Algorithm Flow Chart

II. A METHOD TO LOCATE THE SUN

Actually we are interested in solar tracking system for the solar power tower plant because sun is the basic source for feeding the power towers and thus for the solar generation systems, here we will find the exact location and position of the sun by an algorithm called sun position algorithm. For heliostats positioning toward the sun a solar tracking system is required which will definitely increase the efficiency of the system. The inputs to the master control are also sun position parameters (figure 1).

The inputs and outputs of the sun position algorithm are shown in the (figure 2).

The inputs are given to the C language code and functions process over it, and the output is computed which is the actual position of the sun. C language is used for algorithm because it is more nearer to the machine language and hardware interfacing is easy with a little bit modification [2,5].

Actually the C language code has been built in three parts, the header file with .h extension which contains the declaration of the data types of all the inputs and outputs. The second part is the main window which contains the inputs to be defined by the users and the outputs are shown. The source code part is the long part of the algorithm which contains use of functions, arrays, pointers, structures and enumerations. A funct-ion is a method or procedure which performs a task, the functions are called by pointers and parameters are passed through it. Array is a kind of data structure which stores elements of same data type[5]. Structure is a user defined data type which combines data items of Different types under a single name. Pointer is used for addressing a memory location and every variable has an address on memory location, pointer is used with asterisk sign. Enumeration is a data type consisting of a set of data type which is used to make a program clearer to users [3]. In the source code we have included the data of earth periodic terms in arrays which is a fixed data and will be called by the help of pointers in any function where it is needed.

Following are the functions that are used in the source code for the computation of the outputs from the given input parameters:

Radian to degree

Degree to radian

Limit_degrees

Limit_degrees 180

Limit_zero2one

Limit_minutes

Day_frac_to_local_hr

Third_order_polynomial

Julian_day

Julain_century

Julian_ephemeris_day

Julian_ephemeris_century

Julian_ephemeris_millenium

Earth_periodic_term_summation

Earth_heliocentric_longitude

Earth_heliocentric_latitude

Earth_radius_vector

Geocentric_longitude

Geocentric_latitude

Mean_elongation_moon_sun

Mean_anomaly_sun

Mean_anomaly_moon

Argument_latitude_moon

Ascending_longirude_moon

Xy_term_summation

Ecliptic_mean_obliquity

Ecliptic_true_obliquity

Aberration_correction

Apparent_sun_longitude

Greenwich_mean_sidereal_time

Greenwich_sidereal_time

Geocentric_right_ascension

Geocentric_decination

Observer_hour_angle

Sun_equatorial_horizontal_parallax

Topocentric_right_ascension

Topocentric_local_hour_angle

Topocentric_elevation_angle

Atmospheric_reraction_correction

Topocentric_elevation_angle_correction

Topocentric_zenith_angle

Topocentric_azimuth_angle

Surface_incidence_angle

Sun_mean_longitude

Approx_sun_transit_time

Sun_hour_angle_at_rise_set

Approx_sun_rise_and_set

Rts_sun_altitude

Rts_alpha_delta_prime

Sun_rise_and_set

The method for code usage is described below:

#in calling the program, include the header file to the top of the file by generating the line #include “spa.h”
#declare the SPA structure in calling program spa_data spa;
#the required input values are entered into the SPA structure
#then pass the SPA structure from the called SPA calculates function

The output values will be computed and will return to the passed SPA structure, the output is based on function code selected from the enumeration. A non-zero return code from spa_calculate () indicated that one of the input values did not pass simple bounds tests. The valid input ranges and return error codes are also listed in the header file of the algorithm.

TABLE I. RELATING INPUTS AND OUTPUTS

INPUTS							OUTPUTS							
Year	***Month***	***Day***	***Time*** zone	***Longitude***	***Latitude***	***Elevation***	***Zenith***	***Azimuth***	***Incidence***	***Sunrise***	***Sunset***	***Hour Angle***	***Julian Day***
2001	1	7	+5.0	+106	50	1830.14	147.3	40.15	154.40	05:53:05	14:11:38	202.1	2551917.27
2005	8	7	+6.0	+106	50	1830.14	113.4	7.64	141.39	03:34:37	18:29:23	187.3	2453590.33
2010	2	3	-6.0	+90	40	1230.14	57.11	167.71	27.156	19:06:50	05:21:09	349.2	2455231.55
2015	2	3	-4.0	+80	40	1130.14	73.38	129.16	52.39	21:46:48	08:01:11	309.2	2455231.68
2020	2	3	-4.0	+80	70	1290.13	93.30	131.94	69.93	00:17:48	05:30:50	309.2	2458883.33
2025	4	5	+4.0	+70	70	1290.13	103.5	2.15	132.73	04:03:51	18:44:12	182.1	2460771.35
2030	4	5	+8.0	+70	70	1290.13	94.48	302.33	113.79	04:08:50	22:43:21	122.0	2462597.12
2030	4	5	+3.0	+70	50	1290.13	121.7	20.08	145.44	03:48:27	16:58:02	197.0	2462597.90

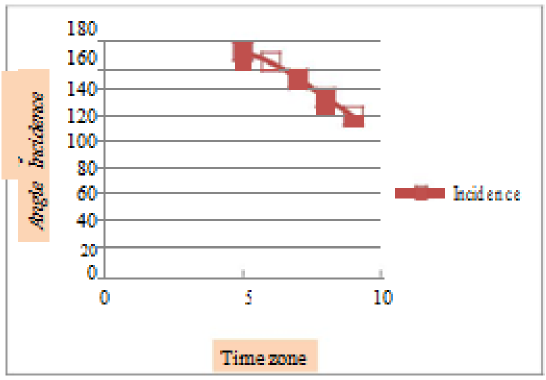

Figure 3. Time Zone vs. Angle of Incidence

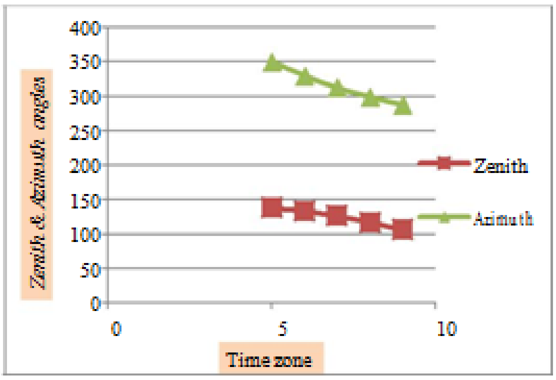

Figure 4. Time Zone vs. Zenith and Azimuth Angles

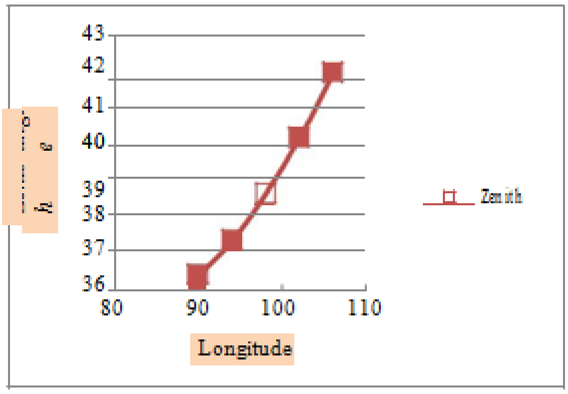

Figure 5. Longitude vs. Zenith Angle

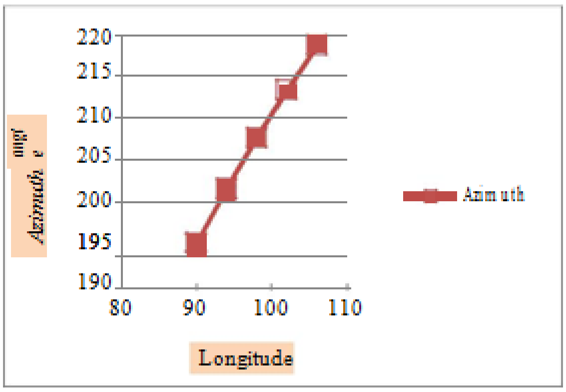

Figure 6. Longitude vs. Azimuth Angle

III. A METHOD FOR CLOUD DEDECTION

Actually a cloud detection system is required for the solar power tower plants because to avoid the damaging of the central receiver due to thermal shocks.

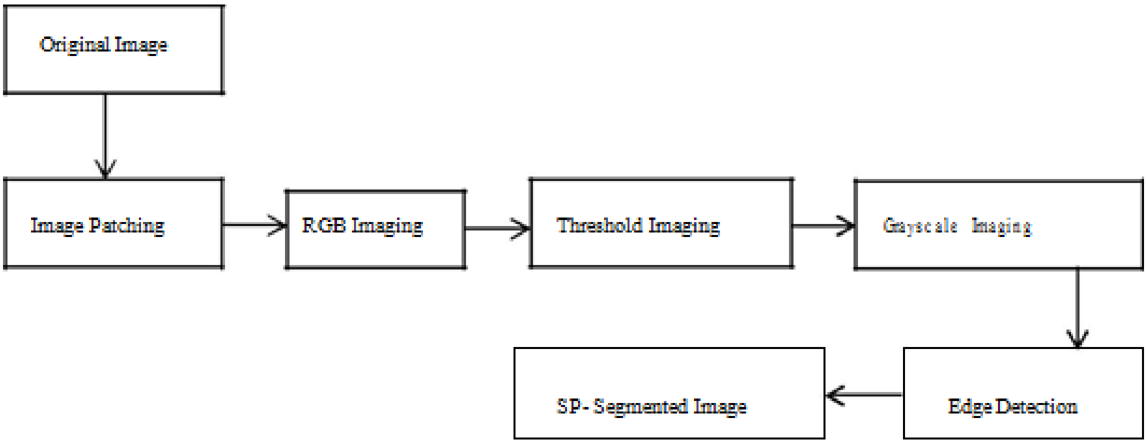

Figure 7. Cloud Dedection System

The clouds will be detected from the original image of the scene by super-pixel segmentation, which is a technique of digital image processing. In image patch ability is provided to select an arbitrary shaped region on the image and replace it with another surface fits to it. Artificial noise is added and unwanted defects are removed in patching. RGB has three channels and each channel can store discrete pixels with conventional brightness, it is used for brightness purpose.Thresholding provides an easy way to perform the segmentation on the basis of different intensities or colours in the background regions of an image.

In threshold each pixel is replaced with a black pixel if the intensity is less than a fixed constant T, and replaced with a white pixel if the intensity is greater than a fixed constant T, in threshold a pixel value may be either 0 or 1[5]. Grayscale images are the black & white sort of images and contain shades of gray color only, in this type the colour information is eliminated and only brightness of each pixel is left, the average of three colours is taken at each pixel value. Edge detection is important because edges are significant local changes of intensity in an image. Important features can be extracted from the edges of an image, like, corners, curves and lines. These features are used by higher level computer vision for recognition purposes; actually edge detection preserves the structure of an image [4]. In segmentation an image is partitioned into sets of pixels called Super-pixels, the goal of segmentation is to make the image more clear and easy to analyse, actually sets of pixels are formed which cover the entire image clearly (figure 7).

CONCUSLION

A method to locate the sun and to segment the clouds has been shown.The information provided here is basic to operate a solar power tower plant in an efficient manner, and these factors will let the master control system to position the heliostats for purpose of tracking the sun to achieve a good efficiency, and to change positions of heliostats away from the sun when the clouds are about to cover the sun, to maintain the integrity of the system and to avoid damaging of the central receiver.

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