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STUDY OF SOLAR RADIATION AND SUN LOCATION AT MIDSUMMER OF A SPECIFIC GEOGRAPHIC POSITION

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ABSTRACT
Incoming solar radiation is the primary driving force for globes biological, physical and industrial systems. Cognition of the amount of solar radiation at various geographic emplacements is desirable for application in such varied disciplines as civil engineering, agriculture, meteorology, ecological research, environmental assessment, forestry and solar energy utilization. This paper introduces the most important parametric quantity such as solar zenith angles, solar Azimuth angle, Surface incidence angle and provides the location of the sun at any time and at any position using SPA (Solar Position Algorithm). Specific case has been studied to analyze the pattern of solar radiation and the solar path at June solstice with two neighboring day before and after the solstices. The results bespeak that the proposed framework can be successfully used to guesstimate the tract of the sun during all the seasons of year for studying position and for considering day, using as input the observer latitude (degrees), observer longitude (degrees), average local pressure, average local temperature and latitude (m). The result of this study shows that the maximum value of solar radiation is obtained at an azimuth angle of 321° throughout the solstice while Topocentric zenith angle and surface incidence angle has the same values.

Keywords: Geographical emplacement, Solar zenith angles, Solar Azimuth angles, Solar Position Algorithm

INTRODUCTION

Mankind has regarded the Sun as the copious source of renewable energy with cipher emission (Abdurrahman et al., 2019). The Earth intercepts about 180×10^6 GW of the power at any time emitted by the Sun. At any given geographic site the amount of sun power received at the earth surface varies in time: Earth's rotation lead to differences in day-night and change in seasons due to the Earth's orbit and Earth's axis inclination. In space also varies at a given time, due to the varying of obliquity of the solar beam with longitude and latitude. Consequently, plan orientation, time and the amount of power received at a certain placement depends upon the relative location of the Earth and the Sun. This is the reason both Sun-Earth geometry and time plays a significant role in solar photo-energy systems and energy conversion (Philippe and Lucien, 2012).

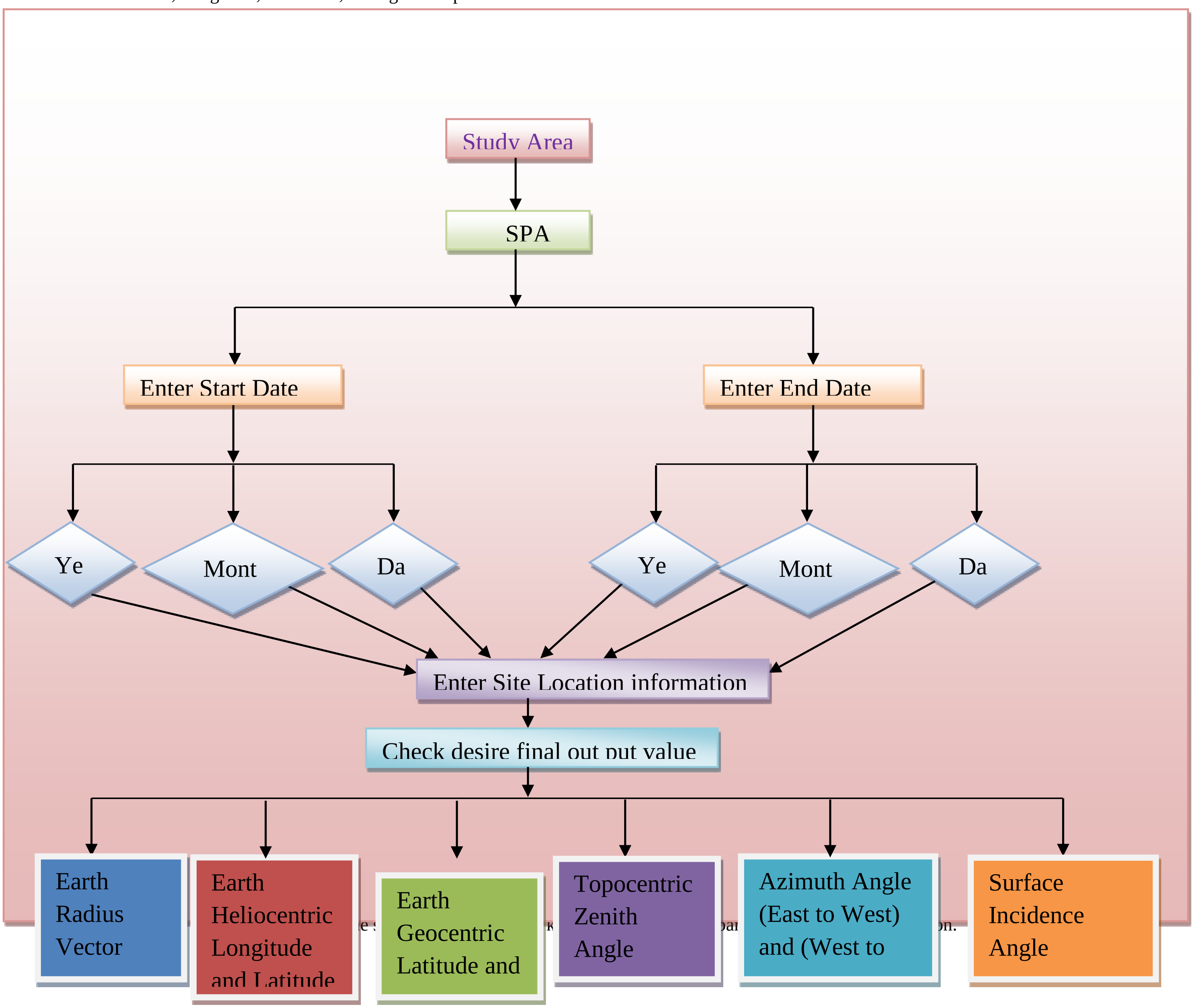
The increasing deployment of such systems and technological advances result in an increasing demand for more accurate knowledge of the location of the Sun with respect to a system. The demand may be indirect, e.g., for computing radiation quantities by models and exploitation of satellite images (Espinar et al., 2009; Perez et al., 2002; Rigollier et al., 2004) or direct, e.g., for pointing a concentrating device or a measuring instrument (Blanco-Muriel et al., 2001; Stafford et al., 2009).Correct acquaintance of Earth-Sun geometry and of time is one of the results reached in astronomy (Bretagnon, Francou, 1988; Meeus, 1999). Algorithms applying have been published and this acquaintance for solar radiation applications exist (Reda, Andreas, 2003, 2004). Their implementation is meant to calculate solar zenith and azimuth angles and other related parameters in the period from -2000 to 6000 with standard deviation of 0.0003° (1"). In practice, time requested for computation may be excessive. Numerous articles have been published in the solar energy field, documenting algorithms for computing the solar location with regard to an observer at a given position on the globe (Blanco-Muriel et al., 2001; ESRA, 2000; Grena, 2008; Kambezidis, Tsangrassoulis, 1993; Michalsky, 1988; Pitman and Vant-Hull, 1978; Walraven, 1978). These algorithms vary in the earned accuracy, in their epoch of legality: from a few years to numerousthousands of years, and in the calculationprice. Various strategies exist to decrease operations, such as reducing the period of validity still keeping a high accuracy (Blanco-Muriel et al., 2001; Grena, 2008; Kambezidis, Tsangrassoulis, 1993), or keeping a large epoch and shrink the accuracy (ESRA, 2000; Michalsky, 1988). Inflowing solar radiation (insolation), with a repetitive input of 170 billion megawatts to the glove, is the prime driver for our planet's biological and physical processes (Geiger 1965, Gates 1980, Dubayah and Rich 1995, 1996).

Solar radiation is the key driving force in ecological process and is often an important ecological parameter. Even though solar radiation for a given location are often available from metrological sources for many purposes it is attractive to be able calculate solar radiation of the specific position. Also, real data may be available for a particular location where a Hadejia Jigawa State, Nigeria study is desirable.

The Solar Position Algorithm (SPA) was premeditated in order to calculate a table of changes in the solar zenith and azimuth angles for a day (or a year) with some input such as average local pressure, longitude, date, time zone, daylight saving time observed and track sun location for peculiar geographic location.

MATERIAL AND METHOD

Firstly a specific location must be selected by finding its latitude, longitude, time zone, average local pressure followed by the distance above sea level using a portable Gps receiver. Hadejia town in Jigawa State, Nigeria was selected as an area of interest for this study with latitude$12°27'2.18"N$, longitude$10°2'25.47"E$ and altitude of 337m. Secondly the remaining input includes; start date, end date and daylight saving time are also inputted. A table of changes in Earth radius vector, Earth Heliocentric Longitude, Earth Heliocentric Latitude, Earth Geocentric latitude, Earth Geocentric longitude, Topocentric Zenith angle, Azimuth angle and Surface incidence angle would generate as part of results. A graph of solar radiation in W/m^2, solar zenith angle in degree, and solar azimuth angle in degree were plotted against time of a day. Figure 1 indicate the methodological workflow.



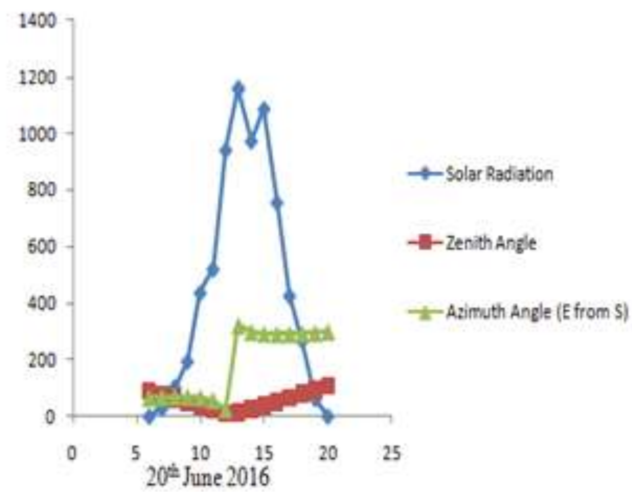


Fig 2: The graph of solar radiation, zenith angle and azimuth angle at 20th June 2016

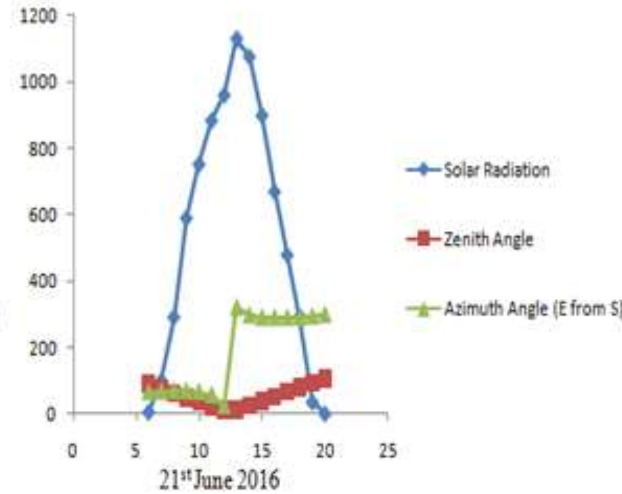


Fig 3: The graph of solar radiation, zenith angle and azimuth angle at 21st June 2016

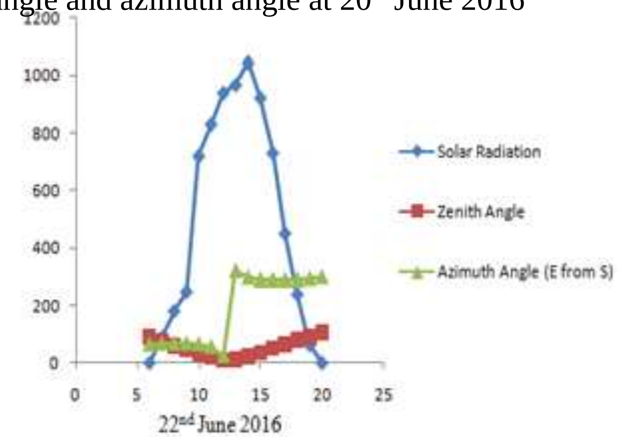


Fig 4: The graph of solar radiation, zenith angle and azimuth angle at 22ndJune 2016

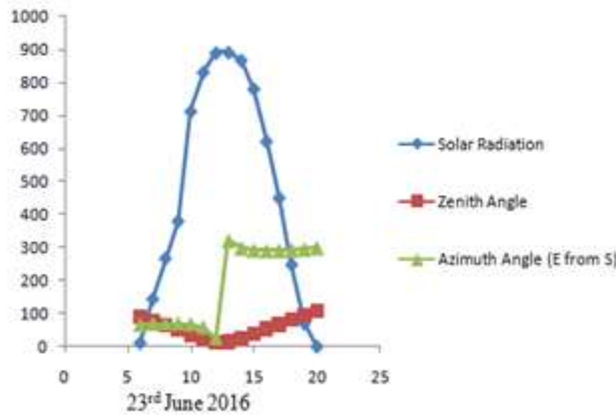


Fig 5: The graph of solar radiation, zenith angle and azimuth angle at 23rdJune 2016

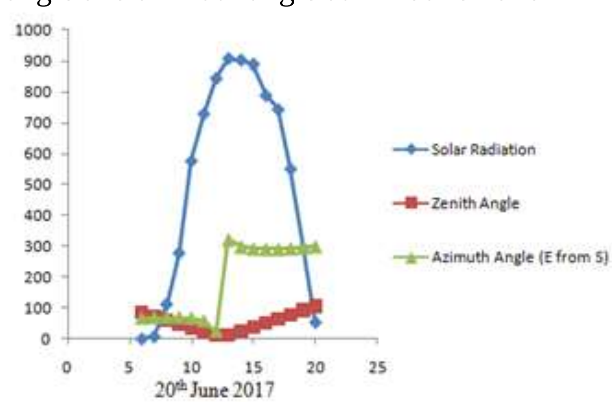


Fig 6: The graph of solar radiation, zenith angle and azimuth angle at 20thJune 2017

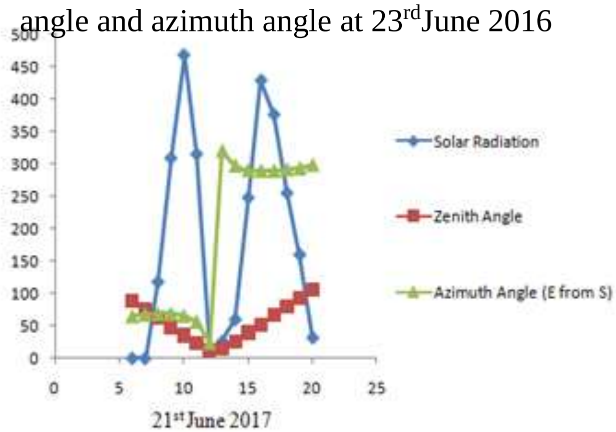


Fig 7: The graph of solar radiation, zenith angle and azimuth angle at 21stJune 2017

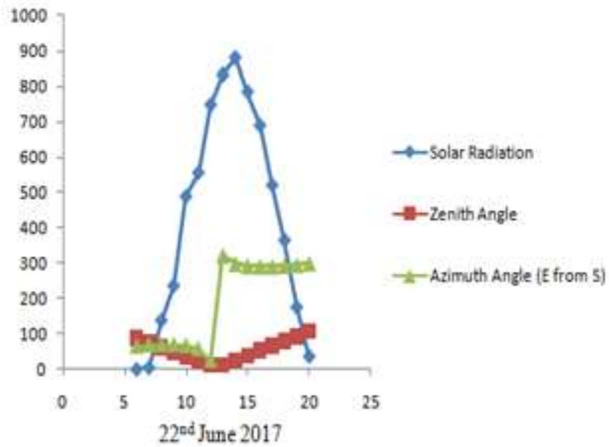


Fig 8: The graph of solar radiation, zenith angle and azimuth angle at 21stJune 2017

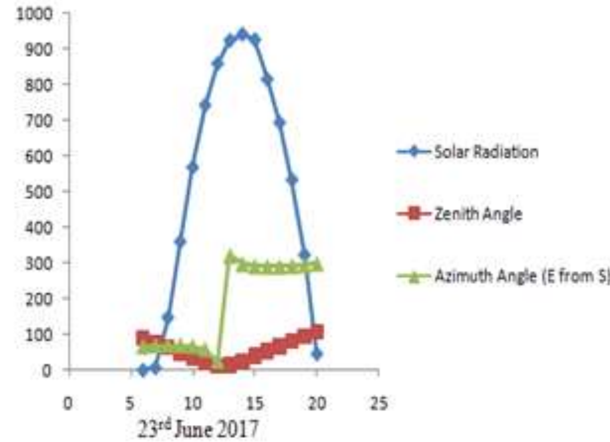


Fig 9: The graph of solar radiation, zenith angle and azimuth angle at 23rdJune 2017

Figure 2, 3, 4 and 5 is the solar radiation, Topocentric zenith angle and azimuth angle graphs for the year 2016 while figure 6, 7, 8 and 9 is the solar radiation, Topocentric zenith angle and azimuth angle graphs for the year 2017. The result show that in three expected day of June solstice solar radiation values for four consecutive days are interchanging but the nature of the paths of the sun are similar even though there is difference in the values of solar radiation, on 20 June 2016 experiences $1160W/m^2$ as the maximum radiation value while 23 June 2017 received $940W/m^2$ this show that the value of solar radiation falling on the earth surface varies yearly but these three months; June, July and August recorded as the high solar radiation zone,

DISCUSSION

MAJOR PARAMETERS OF THE SUN FOR SOLAR POWER CONTRIVE

Let reckon a local observer on the Earth's surface, situated by its geographic longitude λ(rad), latitudeφ (rad) and its distance above sea level h (m) according to a given reference geographical spheroidal. For this local perceiver, at the time j*$_{UT}$, the Sun location can be defined by:

- the Sun topocentric elevation angleγ_S: the angle formed by the horizon and direction of the Sun. Its complementary angle, the Sun topocentric zenith angle, is noted θ_S;
- the Sun topocentric azimuth angle α_S: the angle formed by the projection of the direction of the Sun in the horizontal plane defined eastward from North, following the ISO 19115 standard. The azimuth is the angle which describes the sun's position from east to west (Abdurrahman M, 2019).

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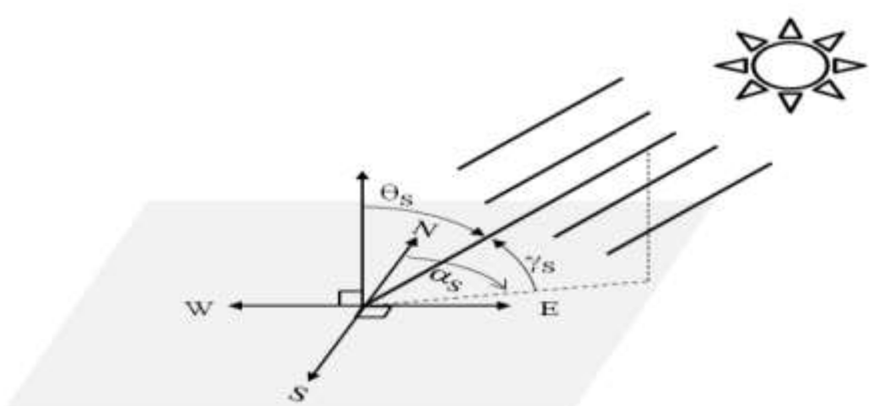

Fig. 10. Sun topocentric elevation angle γ_S, zenith angle $\theta_S$and azimuth angle α_S.

The cosine of the Sun incidence angle θ_I of a tilted plane whose predilection is defined by the surface azimuth angle α also measured eastward from North, and its slope β is given by:

$$\cos\theta_I(\alpha,\beta) = \cos\theta_S\cos\beta + \sin\beta\sin\theta_S\, cos(\alpha_S - \alpha) \quad (1)$$

The most important source of earthly variation of the broadband extraterrestrial irradiance on normal incidence E_0 is due to the earthly variation of the Earth-Sun distance. The broadband solar constant E_{SC} is the average of E_0over a year and corresponds to $E_0$for a distance of 1 AU:

$$E_O = E_{SC}R^{-2} \quad (2)$$

where R is the Earth heliocentric radius expressed in AU.

The value of the broadband solar constant E_{sc} is set to 1367 W/m^2: the typical day-to-day comparative variations of E_{SC} due to solar activity is less than 0.15% and are measured insignificant in the field of solar energy (Schatten and Orosz, 1990; Wald, 2007).

These Sun parameters γ_S, θ_S, α_S, $\cos\theta_I$ and E_0 are commonly used for solar energy studies as they enable for example, the computations of the extraterrestrial surface solar irradiance on a tilted plan, the sunrise and sunset times or the shadow effects due to local horizon.

rth's Surface incidence angle

For hourly time intervals surfaces radiation measurements are generally available. It is essential to guesstimate the ratio of incident radiation on the slanted surface to that on a horizontal surface considering sky diffuse, beam and ground reflected radiation separately in order to find out the hourly incident ration on a surface of any predilection(Liu and Jordan 1963). Appraise ray of radiation on a slanted plane necessitate acquaintance of the position of the sun relative to both the vertical and surface normal. The earth reflected radiation and the incident sky disseminate depend upon the observation constituents between the surface of the ground and the sky. Both factors are constituents are functions of the position of the flat surface relative to the horizontal. The geometry crucial to observe the problem is identifying in terms of three angles as shown in Fig. 11. The incline of the plane, β, is the angle between the plane normal and the vertical. The incidence angle, θ, is calculated between the normal surface and a ray from the sun. The zenith angle, θ_Z, is the angle between a ray of the sun and the vertical (i.e. the incidence angle for a horizontal surface).

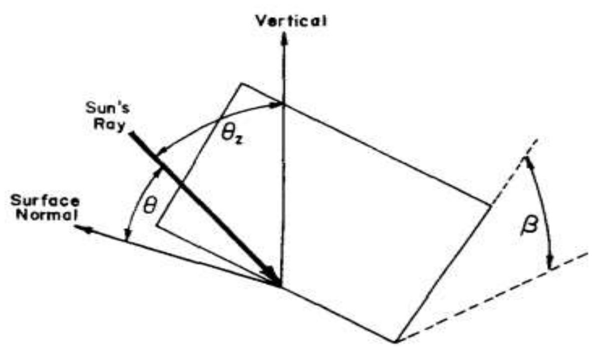

Fig. 11. Geometry necessary for determining incident radiation.

MOTIONS OF THE EARTH IN RELATION TO THE SUN

Solar radiation at any position on the globe is influenced by the motions which the world makes in relation to the Sun. The globe is canted 23.45° from the plane of the globe orbit. At the spring and autumn equinoxes (22 September and 21 March) in the hemisphere the Sun both shines equally. At the winter solstice (22 December) the Sun is directly above your head at 23.45°S and at the summer solstice (22 June in the Northern Hemisphere) the Sun is directly above your head at 23.45°N

Radius vector

The Earth's distances alter with time of year by 3.0%, due to the globe eccentric orbit, during its gyration around the Sun. This eccentricity influences in an insignificant way the amount of solar radiation striking on the globe surface. The radius vector of the globe, R1, conveys this ellipticity and can be measured approximately from the given equation below (Nicholls and Child, 1979)

$$R1 = 1/\{1 + [0.033\cos(360N/365)]\}^{1/2} \quad (3)$$

where the number whose cosine is being taken is in degrees. Over an annual cycle, R1 varies from 0.98324 to 1.01671, so that this correction is not great.

Latitude

Latitude is the other parameter needful to define the geometrical relationships between the Sun and any location on the globe, which is the angular location north or south of the Equator, north positive. The latitude of a position is obtained from geographical maps and for present intends need to be expressed in three significant figures.

Zenith angle

The zenith angle is defined by the location of the Sun and the zenith, the zenith is a point vertically above the location in question. Zenith can be calculated from trigonometric relationships for any point on Earth's for any time of day. It is the intensity of solar radiation on a flat surface which is correlated to the zenith angle.

Summer Solstice

Earth's rotational axis is canted about 23.5° from the orthogonal with respect to the globe orbit around the Sun. As a result, the amount that globe axis canted towards or away from the Sun differs during the year. Summer Solstice or June solstice happens at instant the tilt of the globe axis towards the Sun is at a maximum. The Sun then seem at its maximum distance above sea level at noon for observers in the Northern Hemisphere. Summer Solstice marks the longest day and shortest night of the year in the Northern Hemisphere (Astro, 2018).

The North Pole points towards the Sun for part of the year and it points away for another part of the year. That makes a big difference in how sunshine hits the globe surface. When light the beams hit a surface straight on, they are more powerful and warm the surface more. When beams of sunlight hit at an angle, the warmth is broadening out over a larger area. In the same way, when your part of the world is fusiform more toward the sun, you are getting more sunlight and it is summer (Astro, 2018).

CONCLUSION

Alternative energy is one of the freely accessible natural resources of energy and abundance essentially in every part of the earth. It is the most essential among the substitute source of energy. The ultimate utilization of alternative energy depends upon determining the particular position of the sun location. By using the solar position algorithm (SPA) and metrological data, the solar path for any topographical position can be traced and the study of solar radiation at June solstice was successful using two years data's. Consequently, a vibrant knowledge about the forecasts of alternative energy for any position can be acquired and accordingly determination and, measurement can be implemented for harnessing solar energy of that particular geographical location. The value of solar radiation is related to the azimuth angle; the higher the azimuth angle the higher the solar radiation experienced at the surface of the earth also the surface incidence angle and the angle between the sun and the local observer are equivalent with a constant values every day.

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Appendix 1. Solar Radiation values for a year 2017 (Hadejia Town)

Time	Solar Radiation	Solar Energy	High Solar Radiation
6:00am	0	0.00	0
7:00am	0	0.00	0
8:00am	42	3.61	118
9:00am	166	14.28	309
10:00am	372	32.00	468
11:00am	50	4.30	315
12:00pm	5	0.43	11
13:00pm	17	1.46	26
14:00pm	40	3.44	60
15:00pm	140	12.04	248
16:00pm	332	28.56	429
17:00pm	274	23.57	376
18:00pm	217	18.66	255
19:00pm	90	7.74	160
20:00pm	8	0.69	32
21:00pm	0	0.00	0

21 June 2017

Appendix 2. Solar Radiation values for a year 2017 (Hadejia Town)

Time	Solar Radiation	Solar Energy	High Solar Radiation
6:00am	0	0.00	0
7:00am	0	0.00	5
8:00am	59	5.07	139
9:00am	176	15.14	237
10:00am	349	30.02	490
11:00am	488	41.97	557
12:00pm	634	54.53	749
13:00pm	769	66.14	833
14:00pm	791	68.03	879
15:00pm	745	64.08	786
16:00pm	591	50.83	691
17:00pm	446	38.36	522
18:00pm	271	23.31	366
19:00pm	99	8.52	176
20:00pm	14	1.20	37
21:00pm	0	0	0

22 June 2017