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# The Sun's Placement and Route for Hadejia, Jigawa State, Nigeria

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## Abstract
*The primary source of our energy in the solar system is the sun, and it is the most fundamental among the vital substitute energies of interplanetary weather. Solar energy release at visible wavelengths of the electromagnetic spectrum is fairly constant in time. In addition to this view, to accumulate sun energy, it is necessary to anticipate the sun position comparative to the gathering device. In this paper, an effort has been made to determine the exact placement of the sun for any topographical location of the earth. Solar Azimuth/Altitude reckoner has been used to track the route of the sun and associated Sun data, such as Hour Angle, Altitude Angle, Dayspring and sundown. Here, the position of Hadejia in the state of Jigawa of north-eastern Nigeria has been measured. The highest azimuth angle obtained from the sun is* 323°*in the winter solstice and* 248° *for the summer solstice.*

**Keywords:** Azimuth angle, Altitude angle, latitude, local solar time, solar energy, solar time.

## INTRODUCTION
Mankind has regarded the sun as the biggest source of energy. Solar energy coming down to the earth's surface per year is approximately ten thousand times and the worldwide energy consumption per year. Solar power has the superlative prospective of all the sources of energy that can be renewed (Rai, 2009). Alternative energy is one of the freshest, emanation free and maintainable energy which has been introduced as a remediation to combat the millennium environmental crises (Ozbalta and Kartal, 2010). Harnessing solar energy has consequently, fascinated the consideration of researchers, technicians, economists, sociologists and legislators. Many efforts have therefore been directed towards processing new and better solar energy transition devices. Over time man has been trying to harness the sun as avital energy source. The optimum exploitation of solar energy can be generated after tracing the path of the sun. The sun is one of the promptly accessible cues for spacial preference, and it's generally used between animals (Able, 1991; Wehner, 1992). Because the sun passes through the sky, its use as a compass requires compensation for change over the day in the solar azimuth, the point on the horizon directly below the sun (Sarah., *et al*, 1988). The obtainable suggestion shows that, while the solar azimuth is used, the altitude of the sun in the atmosphere plays no part in avian positioning (Berthold, 1996).The new method was introduced to solve traditional astronomical trigonometric calculations, to overcome the limitations of sunset fixation (to observe the position of the sun at two different points in time) and to obtain a long-term permanent position (Zhang el Al, 2016). In addition, use GMT only to calculate latitude and longitude instead of local time this utilizes the method. A new model for calculating solar location can be created using a sequential mechanism (Zhang el Al, 2016). Yusie *et al* offered the application of Solar Location Algorithm to guesstimate the location of the sun in terms of

azimuth angle and zenith angle (Yusie et al, 2013). Abdallah uses mathematical formulae to predict the sun's movement and need not intelligence the sunlight (Abdallah, 2004).Electro-optical controlled units that use the information of some kind of sensor (e.g., auxiliary bifacial solar cell panel, pyrheliometer) to guesstimate the sun's real location is used in the controller algorithm (Poulek, 2000; Roth, et al).

Solar monitoring systems play an important role in the development of solar energy applications, especially in systems with high solar concentrations that directly convert solar energy into heat or electricity (Luque *et al*., 2007). The closed-loop approach over the past 20 years has traditionally been used in the Sun active tracking scheme (Kalogirou, 1996; Arbab *et al*., 2009). Shanmugam presented a computer program written in Visual Basic to determine the position of the sun and controlled PDS on the east-west or north-south axis to obtain maximum solar radiation (Abdallah and Nijmeh, 2004). The mathematical theory of the distribution of tracking errors was developed to advance the tracking algorithm for the position of the Sun (Badescu, 1982; Badescu, 2008).

**FUNDAMENTAL GLOBE-SUN ANGLES**

The location of any point on the earth's surface with respect to the sun rays is acknowledged at any instant if the hour angle, h, latitude angle, l, and the sun declination angle, d, are known. It is enlightened in Figure 1(Saheli, 2012). The sun seems to travel in a circular trajectory around the earth when observed from a scene on the surface of the earth (Dole, 1962).

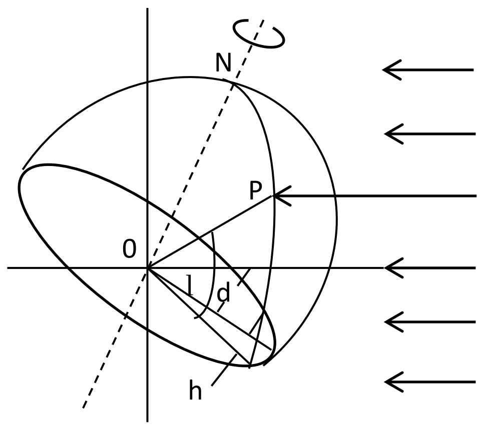


Fig.1 Hour angle, latitude and Sun's declination angles

The quantity of heat energy expected or received at any position on the earth is a direct influence of Sun angle on climate, as the angle at which sunshine strikes the Earth differs by position, time and season of the day callable to the Globe's trajectory round the Sun and the Earth's modification about its lopsided axis. Periodic or recurrent change in the angle of sunshine, instigated by the tilt of the Globe's axis, is the rudimentary instrument that result in warmer weather in summer than in winter (Khavrus, 2010; Khavrus, 2012).

**Latitude**

Latitude is a topographical coordinate that stipulates the north-south location of a point on the surface of the Globe. Is also the angle which ranges from 0°at the equator to 90°at the poles. It is the angle between convexity of OP and OP on the equatorial plane in the North latitudes(Saheli, 2012). The letter O is represented as the center of the earth where north latitudes are measured positive and south latitudes are measured negative.

**Hour Angle**

The 60 minutes or hour angle, h, is the measured angle in the earth's equatorial plane in-between the convexity of the OP and the convexity of a contour from the midpoint of the sun to the epicenter of the globe. The hour angle converts the confined (local) solar time (LST) into the number of degrees which the sun travels diagonally through the sky. By classification, at solar noon the hour angle is $0^{\circ}$. Since the earth rotates $15^{\circ}$ in every hour, each hour away from solar noon representing an angular motion of the sun in the atmosphere of $15^{\circ}$ in the sunrise the hour angle is negative in the midafternoon the hour angle is positive. One hour of a time is characterized by $180/12 = 15°$that of hour angle (Rai, 2009).

$$HRA = 15°(LST - 12) \qquad (1.0)$$

**Declination Angle**

Declination is the angle of the sunshine south or north of the World's equator (See fig 2).

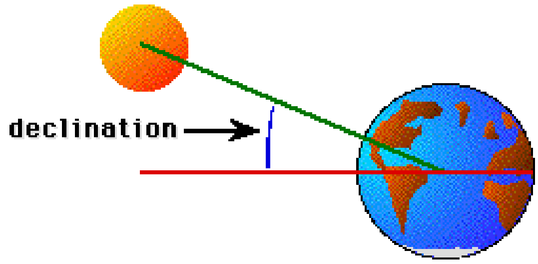


Fig 2: Declination angle (Eric, 1995)

The line drawn between the sun and the center of the earth, the angle between the world's equatorial plane and this line is called the declination (Pitak and Kawin, 2008). When the sun's beams are at north of the equator the declination is positive and negative at south of the equator. During the time of winter solstice, the sun's beams are at $23.5^{\circ}$ south of the globe's equator and the sun's beams are $23.5^{\circ}$ north of the globe's equator, at the time of the summer solstice ( See Fig.3).

On the other hand, the declination can be assumed to be the angle between the elevated point for an observer on the equator and the location of the sun at midday on a specified day (Goswami and Kreider, 2000).

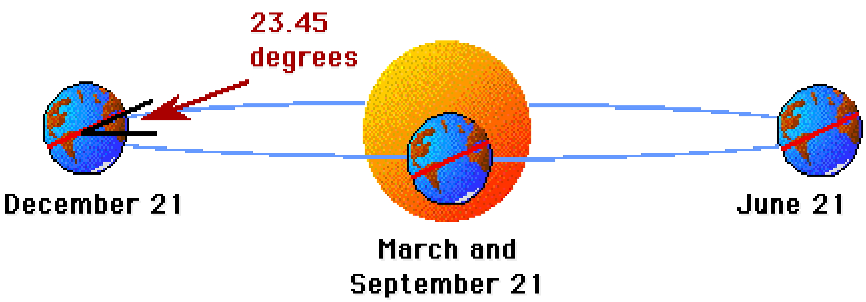


Fig 3: Declination angle in winter and summer solstice (Eric, 1995)

At vernal and autumnal equinoxes the sun's declination angled = 0. The declination angle can be calculated using the formula.

$$d = 23.45 \sin[360/365\,(284 + n)(284 + n)](degrees) \qquad (2.0)$$

where d =is the declination angle, n = is the day of the year, January 1= day 1

**RELATION BETWEEN SOLAR TIME AND MERIDIAN CLOCK TIME**

The Sun's position can be calculated in term of solar time. Sun location can be obtained when transforming local clock time into solar time. The transformation between the clock time and solar time involves information about the position, the 365 days, and the conditions to which local clocks are primed (Wu *et al*., 2008). Time of Greenwich meridian (zero longitude) can be termed Greenwich Universal Time or Civil Time.

Such time is conveyed on an hour gauge from 0 to 24. Local Civil Time is established from the particular longitude of the observer. On any specific meridian, Local Civil time is more advanced at the same instant than on any supplementary west and less advanced than on any meridian further east (Saheli, 2012). The difference amounts to 1/15 hour (4 minutes) of time for each degree difference in longitude. Clocks are mostly set to give the same interpretation during an entire area with a span of about 15° of longitude. The time retained in each such area or zone is Local Civil Time of a meridian near the center of the area. Such time is called Standard Time. A solar day is marginally altered from a 24 hours civil day due to the abnormalities of the earth's revolution, obliquity of the globe's revolution and some other factors. The modification in-between Local Solar Time, LST and Local Civil Time, LCT is well-known as the equation of time (Saheli, 2012).
The clock time and solar time can be concomitant as:

$$LST = CT + (1/15)(L_{STD} - L_{loc}) + E - DT \quad [hr](3.0)$$

$$where, LST = Localized\ solar\ time\ [hr]$$

$$CT = Clock\ Time\ [hr]$$

$$L_{STD} = Standardized\ zenith\ of\ the\ local\ time\ zone$$

$$L_{lol} = Longitude\ of\ real\ position\ [degree\ west]$$

$$E = Equalization\ of\ time\ [hrs]$$

$$DT = Daylight\ Saving\ Time\ correction,$$

$$E = 0.165 \sin 2B - 0.126 \cos B - 0.025 \sin B\ [hrs](4.0)$$

Equation of time, E values are premeditated as (Saheli, 2012)
where$B = \frac{360(n-81)}{364}$ and n is the number of days in a year.

Consequently, longitude chastisement and the equation of time are to be considered to relate local solar time with clock time too apart from daylight saving time. As the earth moves around the sun, solar time changes slightly with respect to local standard time (Benghanem, 2011).

Solar hour angle, h can be calculated after computing Local Solar Time. As hour angle varies by 15° per hour therefore hour angle h = 0 at solar noon, while before solar noon it is negative, hour angle equation h can be given by (Saheli, 2012)

$$h = 15(LST - 12)[degrees](5.0)$$

**Longitude Chastisement**

Sun passes over the meridian at a certain moment for all spaces positioned on the same meridian. If two places are not located on the equal meridian at that time they will have a dissimilar local solar time, varying by four minutes for each degree alteration in longitude. To compute the Longitude chastisement, the longitude of the time zone meridian is to be deducted from the local meridian of the location being deliberated (Saheli, 2012).

**ALTITUDE ANGLE AND AZIMUTH ANGLE**

The azimuth angle is the angle between the horizontal planes measured from true south to the horizontal projection of the sun's rays (Saheli, 2012). The Azimuth angle $\theta_Z$isnegative for west of south route and is positive on east of south route. Altitude and Azimuth angles are established by means of the time of the day, the latitude, and numbers of days in a year. The Altitude and Azimuth angles are two significant parameters for solar design projects (Guo *et* *al*, 2012). The solar azimuth angle measures the relation of the sun facing south; depending on the same three angles as the solar altitude angle (Shibayama and Wiegand, 1985). Azimuth angle is measured in the horizontal plane between the due-south direction and the projection of the sun-earth line onto the horizontal plane (Elhab *et al*, 2012).

The solar altitude angle is the angle in-between the parallel plane of the area and at a point on the earths surfaces a default line linking the point on the earth and the sun (Saheli, 2012). The zenith angle is the angle between the sun's beam and the local vertical or upright.
Figure 4displaysthe Altitude angle, azimuth solar angle, and zenith angle represented by $\gamma$,$\alpha$ and $\theta_z$ respectively.

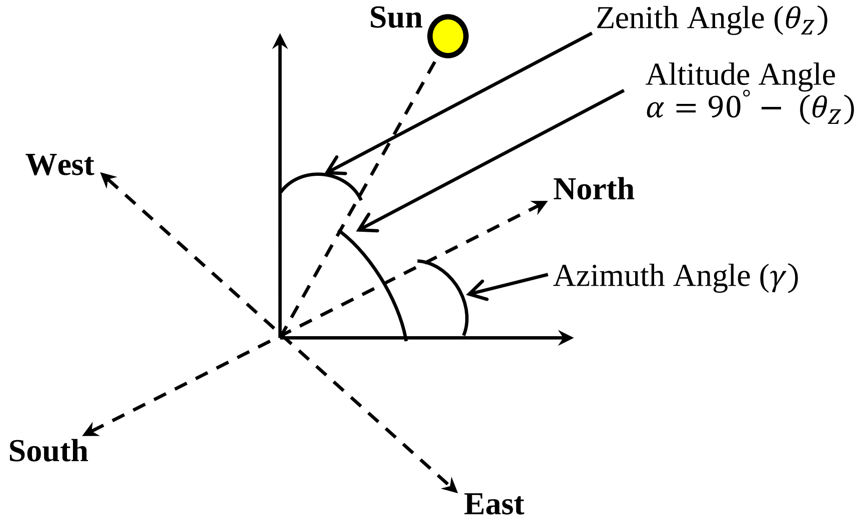


Figure 4: Location of Sun Position (Eric,1995)

In the west route of south the sign conventionality applying for azimuth angle is positive and is negative in the east itinerary of the south. This outcome is always taking the same sign in azimuth angle of the sun and hour angle.

## METHODOLOGY

The Keisan computer program calculator was designed in order to calculate a table of changes in the solar altitude and azimuth angles the system is called ALTI-AZIMUTH. With a perceptive value, the system exact location and route of the sun will be determined for a day in the afternoon (6:00pm) with some input such as latitude, longitude, date, time zone, daylight saving time etc.

Firstly, a specific location must be selected by finding its latitude and longitude followed by the distance above sea level using portable GPS receiver, Hadejia Local Government in Jigawa State was selected because the location of the sun must be established for one topographical point, where the measurement will be done. Secondly the remaining inputs; date, time zone, daylight saving time are also inputted in Keisan calculator. Lastly after all required information where inserted then an execution button was provided so that a table of changes in the solar elevation with azimuth angles appeared on the Keisan screen. A graph of angle in degrees was plotted against time in hours to show the azimuth angle of that day four different graphs were plotted for various azimuth angles with different path of the sun.

**RESULTS AND DISCUSSION**

Location of the sun's in the sky can be verbalized in terms of altitude angle and azimuth angle. A computer program has been formulated which takes time and date as input and executes the azimuth and solar altitude angles as an output for a peculiar topographical position. The program takes into account on the day-to-day as well as seasonal distinction of the solar route. Consequently, for a given date and time, we can now track route of the sun follows at a peculiar location.

The results exhibited that there is a substantial difference of the sun track at dissimilar time and date of the year as shown in the three tables below (Table 1. 2 and 3). Knowing the topographical position in terms of longitude and latitude, the route tracked by the sun can be traced for any position of the globe.

The graphs in Fig. 6 and Fig. 9 show the location of the sun on two days: December 22nd (summer solstice) and June 21st (winter solstice) in the Southern Hemisphere. There are two altitude curves in Fig. 6 and Fig.9. They show that the sun, in summer (December 22nd), is at 0.3° at about 6:00 in the morning, has its maximum height (≈80°) about midday and about 19:00 h is at 0° again. Noticeably, the curve for June 21 is similar, but the maximum is smaller (≈50°), the sunrise is later and the sunset earlier. The curves for all other days of the year are between those stated above.

The azimuth is the angle which describes the sun's position from east to west. The two curves in Fig. 6 and Fig. 9 show the sun's motion in summer and winter. Both curves have an azimuthal angle of 0° at midday. It is at a different time in summer and winter, due to the summer–winter change of time in Hadejia, Jigawa *State*.

Table 1: Solar path for 26th May, 2018 for Hadejia (latitude = 12.450605 and longitude = 10.040407

| **Clock Time (hr)** | **Azimuth Angle (degree)** | **Altitude Angle (degree)** | **Solar Time (hr)** | **Hour angle (degree)** |
|---|---|---|---|---|
| 4.00 | 58.6 | −25.6 | 3.72 | −124.18 |
| 5.00 | 64.3 | −12.7 | 4.72 | −109.18 |
| 6.00 | 68.1 | 0.7 | 5.72 | −94.18 |
| 7.00 | 70.7 | 14.5 | 6.72 | −79.18 |
| 8.00 | 72.1 | 28.3 | 7.72 | −64.18 |
| 9.00 | 72.2 | 42.3 | 8.72 | −49.18 |
| 10.00 | 69.9 | 56.2 | 9.72 | −34.18 |
| 11.00 | 61.2 | 69.6 | 10.72 | −19.18 |
| 12.00 | 23.3 | 80.1 | 11.72 | −4.18 |
| 13.00 | 312.6 | 76.3 | 12.72 | 10.82 |
| 14.00 | 293.6 | 63.7 | 13.72 | 25.82 |
| 15.00 | 288.7 | 50.0 | 14.72 | 40.82 |
| 16.00 | 287.7 | 36.1 | 15.72 | 55.82 |
| 17.00 | 288.4 | 22.2 | 16.72 | 70.82 |
| 18.00 | 290.3 | 8.3 | 17.72 | 85.82 |
| 19.00 | 293.4 | −5.3 | 18.72 | 100.82 |

Table 2: Solar path for 21st June, 2018 for Hadejia

| Clock Time (hr) | Azimuth Angle (degree) | Altitude Angle (degree) | Solar Time (hr) | Hour angle (degree) |
|---|---|---|---|---|
| 4.00 | 55.4 | −25.3 | 3.64 | −125.34 |
| 5.00 | 61.3 | −12.8 | 4.64 | −110.34 |
| 6.00 | 65.3 | 0.3 | 5.64 | −95.34 |
| 7.00 | 67.8 | 13.8 | 6.64 | −80.34 |
| 8.00 | 69.0 | 27.4 | 7.64 | −65.34 |
| 9.00 | 68.7 | 41.1 | 8.64 | −50.34 |
| 10.00 | 65.6 | 54.6 | 9.64 | −35.34 |
| 11.00 | 55.8 | 67.5 | 10.64 | −20.34 |
| 12.00 | 22.6 | 77.2 | 11.64 | −5.34 |
| 13.00 | 323.3 | 75.1 | 12.64 | 9.66 |
| 14.00 | 300.1 | 63.9 | 13.64 | 24.66 |
| 15.00 | 293.1 | 50.7 | 14.64 | 39.66 |
| 16.00 | 291.0 | 37.1 | 15.64 | 54.66 |
| 17.00 | 291.2 | 23.4 | 16.64 | 69.66 |
| 18.00 | 292.8 | 9.9 | 17.64 | 84.66 |
| 19.00 | 295.7 | −3.5 | 18.64 | 99.66 |

Table 3: Solar path for 22nd December, 2018 for Hadejia

| Clock Time (hr) | Azimuth Angle (degree) | Altitude Angle (degree) | Solar Time (hr) | Hour angle (degree) |
|---|---|---|---|---|
| 4.00 | 110.9 | −36.4 | 3.70 | −124.52 |
| 5.00 | 111.2 | −22.7 | 4.70 | −109.52 |
| 6.00 | 112.9 | −9.1 | 5.70 | −94.52 |
| 7.00 | 115.9 | 4.2 | 6.70 | −79.52 |
| 8.00 | 120.4 | 17.2 | 7.70 | −64.52 |
| 9.00 | 127.2 | 29.4 | 8.70 | −24.13 |
| 10.00 | 137.3 | 40.2 | 9.70 | −34.52 |
| 11.00 | 152.5 | 48.7 | 10.70 | −19.52 |
| 12.00 | 173.1 | 53.2 | 11.70 | −4.52 |
| 13.00 | 195.6 | 52.0 | 12.70 | 10.48 |
| 14.00 | 214.2 | 45.8 | 13.70 | 25.48 |
| 15.00 | 227.2 | 36.1 | 14.70 | 40.48 |
| 16.00 | 235.8 | 24.6 | 15.70 | 55.48 |
| 17.00 | 241.6 | 12.1 | 16.70 | 70.48 |
| 18.00 | 245.5 | −1.0 | 17.70 | 85.48 |
| 19.00 | 248.0 | −14.5 | 18.70 | 100.48 |

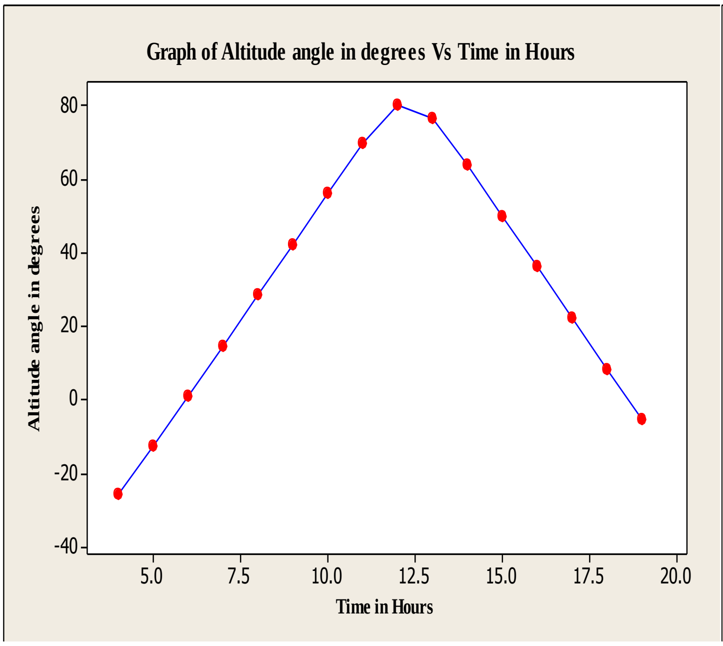


Fig. 3 Graphical output of altitude angle for 26th May for the location of Hadejia

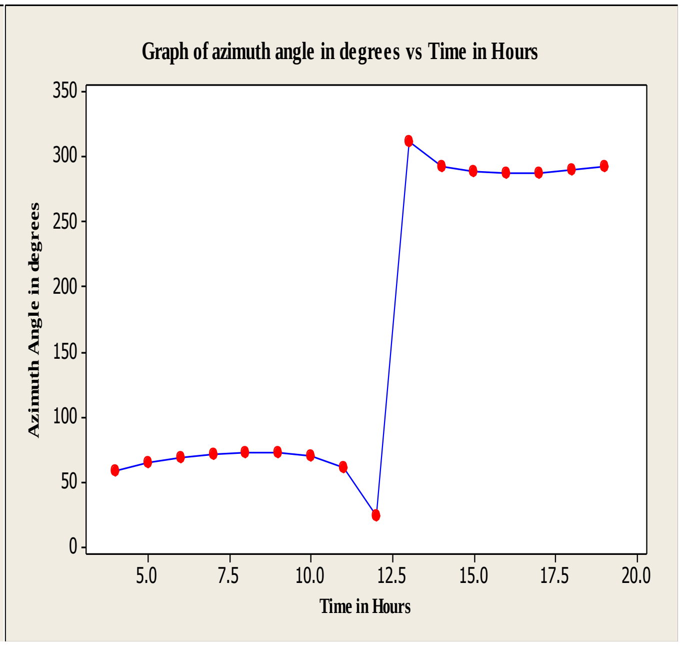


Fig. 4 Graphical output of azimuth angle for 26th May for the location of Hadejia

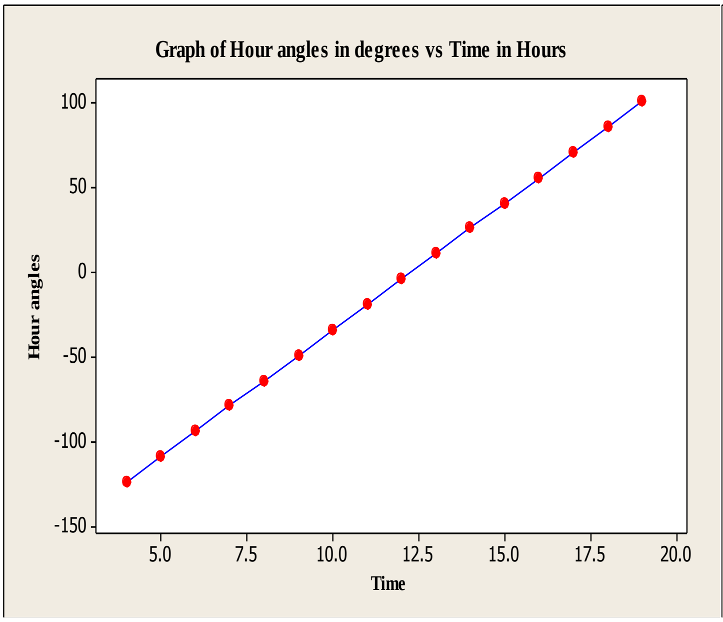


Fig. 5 Graphical output of Hour angles for 26th May for the location of Hadejia

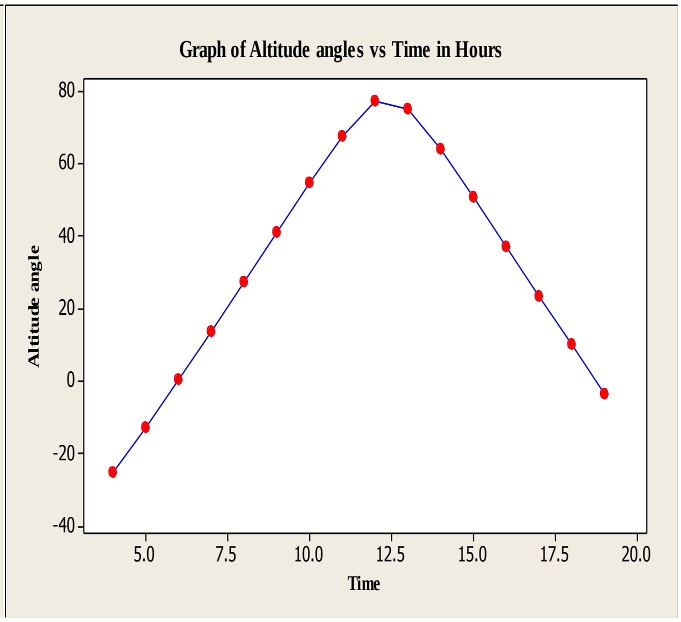


Fig. 6 Graphical output of altitude angle for 21st June for the location of Hadejia

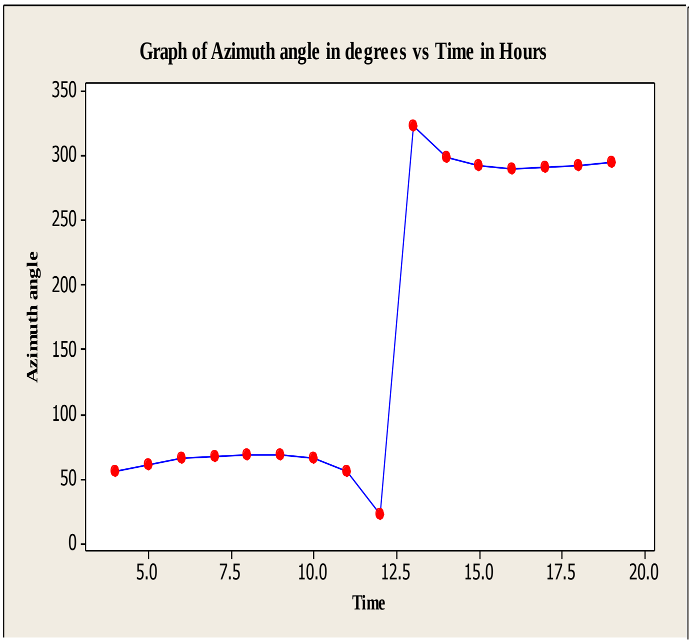


Fig. 7 Graphical output of azimuth angle for 21st June for the location of Hadejia

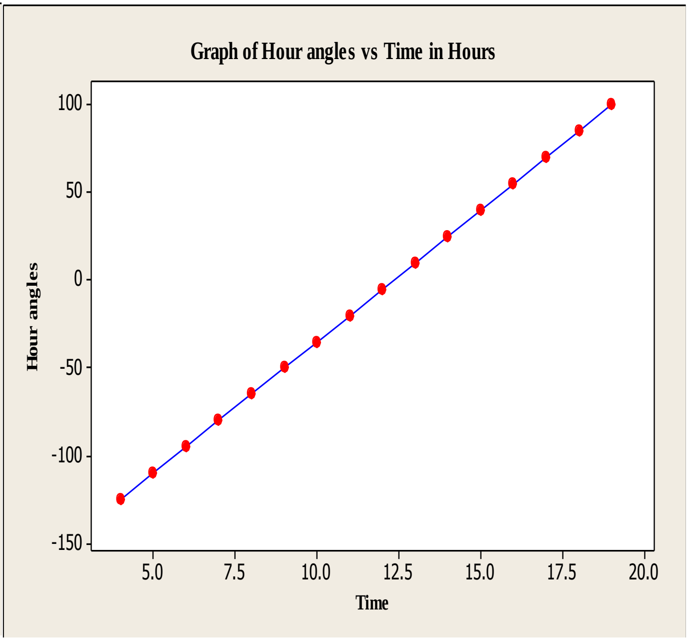


Fig. 8 Graphical output of Hour angle for 21st June for the location of Hadejia

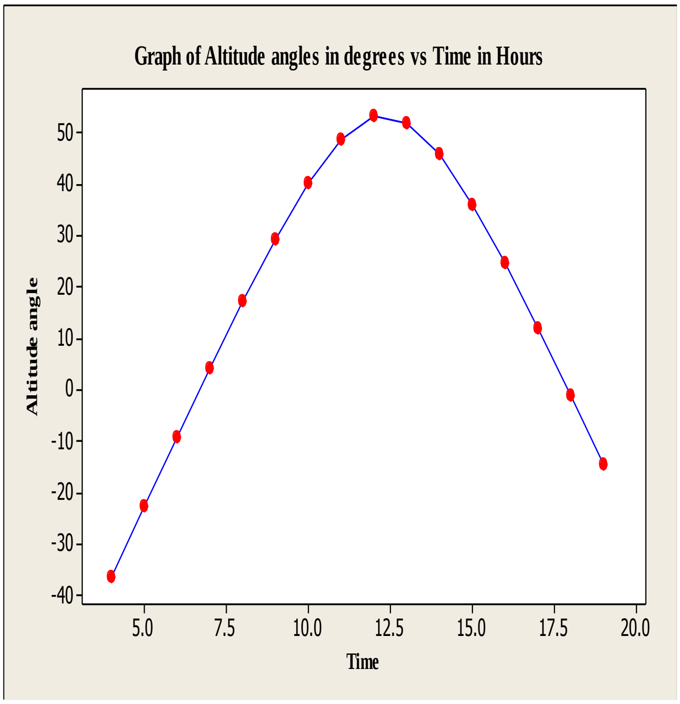


Fig. 9 Graphical output of altitude angle for 22nd December for the location of Hadejia

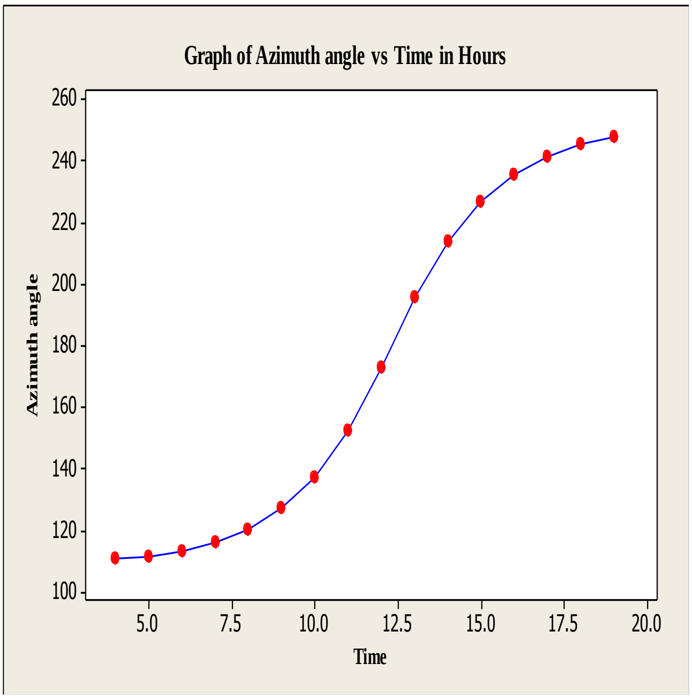


Fig. 10 Graphical output of azimuth angle for 22nd December for the location of Hadejia

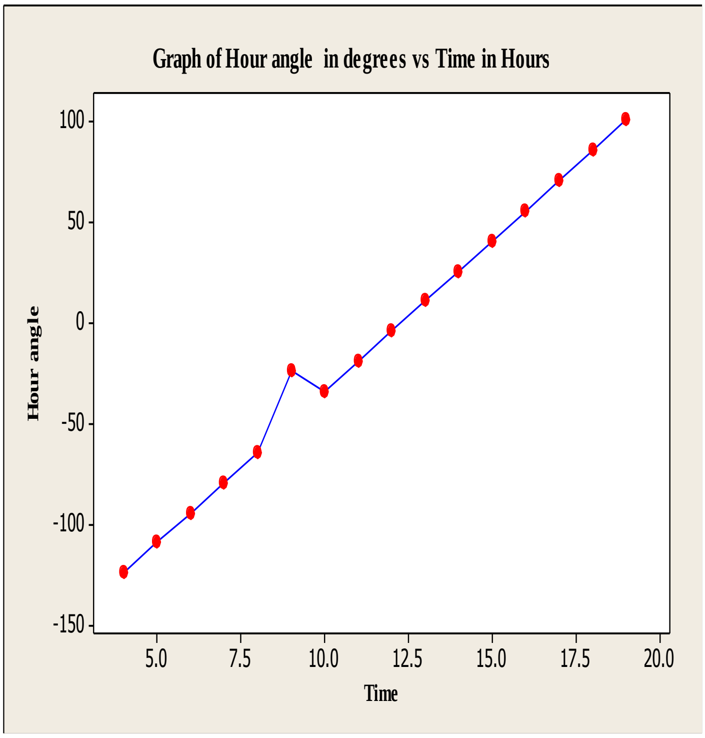


Fig. 11 Graphical output of Hourangle for 22nd December for the location of Hadejia

The curves of altitude angle, azimuth angle and hour angle for 21st June and 22nd December are shown in Fig.6-Fig.7-Fig.8 and Fig.9-Fig.10-Fig.11 respectively. 21st June corresponds to the longest day and 22nd December corresponds to the shortest day. The altitude and azimuth angles of the remaining 363 days, their value will lie between that of longest and shortest day of that particular year.

## CONCLUSION

Alternative energy is one of the freely accessible natural resources of energy and abundance essentially in every part of the universe. 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 appropriate reckoning and computer programs, the solar track for any topographical position can be traced. 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 result show that in June 21st the azimuth angle range from 323° to 22.6°, the altitude angle from 77° to $-3.5°$, the hour angle from 99.66 to $-5.34$, while for December 22nd the azimuth angle lies in-between 248° to 110.9°, the altitude angle from 53.2 to $-1.0$ the hour angle from 100.48° to $-4.52°$ respectively.

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