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A REVIEW OF DESIGN AND CONSTRUCTION OF A SOLAR TRACKER FOR A PHOTOVOLTAIC BOARD

(A Lasting Solution for Non-Electrified Remote Areas in Nigeria)

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ABSTRACT: ***In recent years, solar energy has shown to be one of the most effective and cleanest energy sources that has the potential to displace fossil fuels. Numerous studies have been conducted in this field of renewable energy to increase solar cell production and make it more affordable. One of the best and most distinctive ways to boost the efficiency of solar cells is by using a solar tracker. This results in the adoption of an automatic solar tracker methodology. This project's results have outperformed conventional solar panels that are permanently attached to harnessing solar energy. After the successful completion of the prototype, it was discovered that the tracker can rotate and track the direct sunlight, which accounts for approximately 90% of the output voltage. This information was used to validate our research. According to predicted estimations from the planned solar tracking system, tracking enhances system efficiency by roughly 30%.***

Keywords: **Photovoltaic Cells, Renewable Energy, Solar Tracker, Electricity Generation.**

1.0 INTRODUCTION

Recent studies on energy generation have centered on renewable energy and how important it is given the rising cost of fossil fuels. One of them is how to increase the solar cell's output. By so doing, the solar panel tracking system is designed [1]. A solar tracker can be defined as devices that track solar radiations [2]. All concentrator applications use solar tracking systems since these devices cannot generate energy until tilted closely toward the direction of the sun [3]. The foundation for which the development of the proposed project will be undertaken is to mitigate the effects of epileptic power supply and total blackout scenarios that have been observed in most remote villages as well as communities, thereby providing a substitute power supply for the typical Nigerian home. Nigeria has a lot of potential for solar and wind energy resources, but they have not yet been used to generate electricity for the country's people. The aggregate reserves of these renewable energy sources are around 1.5 times greater than those of the traditional ones. Because of this, the suggested design will maximize this capability in order to continuously supply power utilizing solar energy.

The implementation of building the solar tracker for the PV board in Cross River State, Nigeria, would be carried out for the interior community in the south-south geopolitical zone identified by this research as having a very high solar irradiation potential. LDR, LCD, microcontroller, stepper motor, and its driving circuit will all be included in the intelligent circuitry used in the suggested project.

There are eight sections to the research. A quick overview of renewable energy, the need to investigate further solar energy applications like the solar tracker, and the study's goal are presented in the first units. A description of solar tracking systems is given in Section 2. The description, component specifications, designs, and construction of the solar tracker system are presented in Section 3. The PV solar tracker operation solutions in section 4 are illustrated in section 5. The findings and discussions are presented in Section 6. Finally, section 7 provides the conclusion and advice.

2.0 AN OVERVIEW OF SOLAR TRACKING SYSTEMS

The amount of solar irradiance that strikes the solar panel's surface directly relates to how efficient solar cells are. Given this, a system or process that tracks the sun in order to capture more solar radiation is essential. Although the levels or percentages vary, research has demonstrated that tracking systems boost the output of the cells [4]– [5].

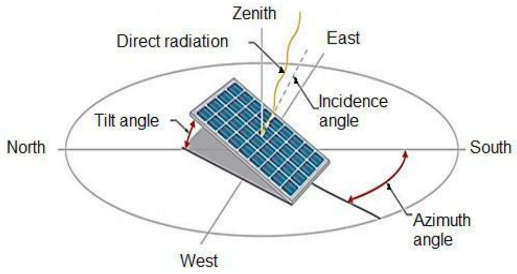


Figure 1.0: The Tilt and Azimuth Angles of the Solar Panel [20]

As this field of study develops, we learn that single- and dual-axis trackers have unique advantages and corresponding modes of operation. [6], [7], [8]– [9] [10] [11] [12] [13].

2.1The Solar Power Tracker System

There are four main parts to a solar power tracking system. These include the battery, the inverter, the charge controller/regulator, and the solar cell.

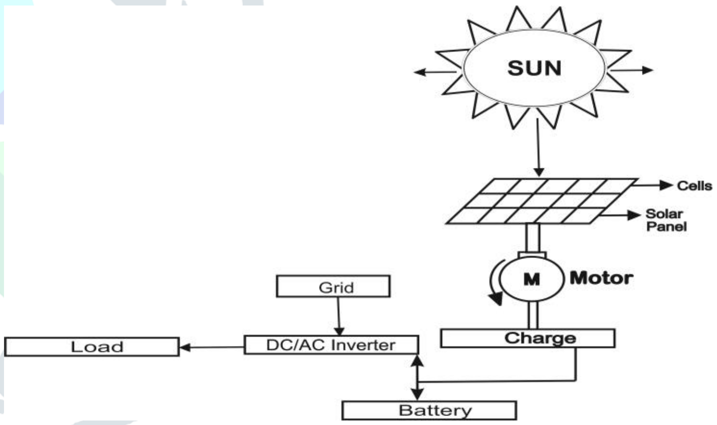


Figure 2.0: A Typical Design of the Solar Power Tracking System

Direct current is provided by the solar cells and is controlled by the controller before being sent to the battery. The saved DC was converted into an AC by an inverter for effective utility use. The foundation of this tracking system is the microprocessor. Tracking systems use the action of photodiodes to turn the solar panel face towards the sun, ensuring that solar panels are constantly at right angles to the sun's beams at all times. This produces maximum output power throughout the day. Three fundamental types of solar trackers exist: single axle, double axis, and concave mirror. In order to keep the design straightforward and the component counts low, this research will use both hardware and software, with the fully intelligent and regulated function implemented in the program.

For increased efficiency, the design includes a PLC microcontroller, stepper motor and its driving circuit, LDR, and LCD display for voltage monitoring and display.

In order to detect the location of the sun and the efficiency with which a solar panel can convert solar irradiance into electrical energy, the LDR (light-dependent resistance) will be utilized as a light sensor. One of the ADC (Analogue to Digital Converter) inputs on the microcontroller will be used to monitor the solar cells' efficiency. A 16 by 2-character liquid crystal display will show the voltage levels.

2.2 Concept of Design

The main purpose of the recommended solar tracker is to maintain or make sure that the solar panel always faces the direction that the sun is moving [14].

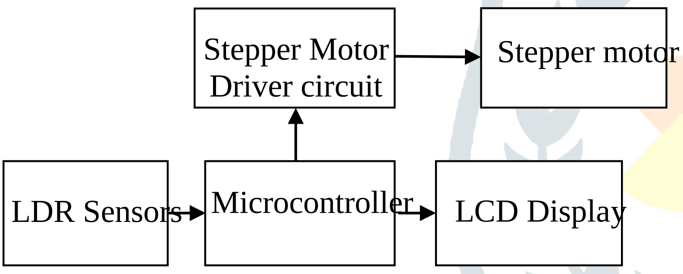


Figure 3.0: Block Diagram of a Tracker

A turning mechanism in the form of gear and actuators is mounted on the solar tracker assembly to accomplish this operation. An intelligent monitoring and tracking controlled circuit that activates if the light sensor is out of alignment with the sun will run this gadget. This will tilt the solar receptors so they are toward the sun.

2.3 Methodology of the Solar Tracker System

The proposed design will be constructed with clever/sensitive circuitry that includes a stepper motor, LCD, microprocessor, and drive circuit. LDRs and solar panels will be combined at two different places in the proposed architecture. LDR changes its resistance according to the amount of light it receives. On the other hand, the microcontroller also reads and tracks the solar panel voltage before displaying it on an LCD screen.

2.3.1 Operating Conditions of the Solar Cell

Open and short circuit processes are both possible in solar cells. Contrary to popular assumption, these cells don't just produce direct current; instead, it has been found that they also form clusters or harmonies of alternating current. As a result, some manufacturers frequently include a full-wave rectifier with a Schottky diode.

2.3.2 Power Characteristics of Solar Cells

The solar cell's output power (V*I) is temperature-dependent [16]. Wikipedia has information on solar power systems. The output voltage can be decreased by 3 to 10 volts by the load resistance. For instance, a 125-watt, 17.5 volts, and 7.14-amp 12-volt panel

Power = V*I……………………… (1)

= 17.5*7.14

= 124.95W = 125W

However, actual power might be 120W. That is 17.1v * 7.0A = 119.7W = 120W.

2.3.3 Analysis of Solar Energy Efficiency/Losses

The percentages of power converted and collected when the solar cell is linked to an electrical circuit are known as solar energy efficiency/losses [17].

n =P/ExA……………….…………… (2) The temperature and irradiance for the standard test conditions were 250C and 600W/m2, respectively, with a 1.5 air mass.

2.4 The Inverter

A device that can transform DC electricity into 220V, 50Hz AC power is known as an inverter. [18]. Additionally, the majority of inverters come equipped with internal battery chargers that can quickly charge batteries when an alternating current source, like a generator or the mains, is utilized as the inverter's input. Additionally, it has an auto-transfer switch that enables switching between alternating current sources for certain loads.

2.5 The Battery

Although there are many different types of batteries in use today, deep-cycle batteries are mostly used in solar power systems [14]. Because these batteries can be completely depleted and then recharged thousands of times, this is possible. For instance, a

12V 150AH battery has a maximum total wattage of 150 x 12 = 1800W = 1.8KWh.

A 150AH battery that is fully charged may also deliver a constant 12V to the inverter for 16 hours. However, the battery's internal leakage reactance must be taken into account [18].

2.6 Charge Controller

There are charge controllers that can be disconnected at low voltage. With the help of this function, loads may be connected to the voltage-sensitive low-voltage disconnection terminals. The loads are disconnected to prevent potential harm to the battery and loads if the battery voltage falls much below the lowest permissible level.

3.0 DESIGN PROCEDURE OF THE SOLAR TRACKER/CONSTRUCTION

3.1 Build of the Tracker

The tracker's software component is exact. As can be seen from the schematic diagram, the hardware was designed using the C programming language. There are only a few pairs of passive components, as well as LEDs for the "user interface".

3.2 Hardware and Software Design

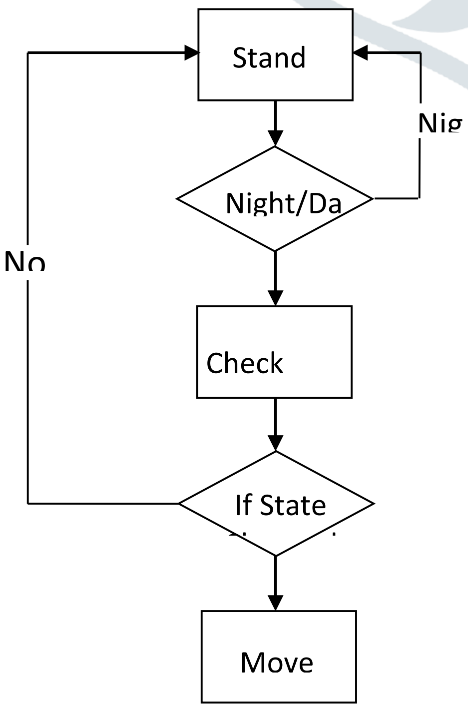


Figure 4.0: Flowchart diagram for the solar tracking system

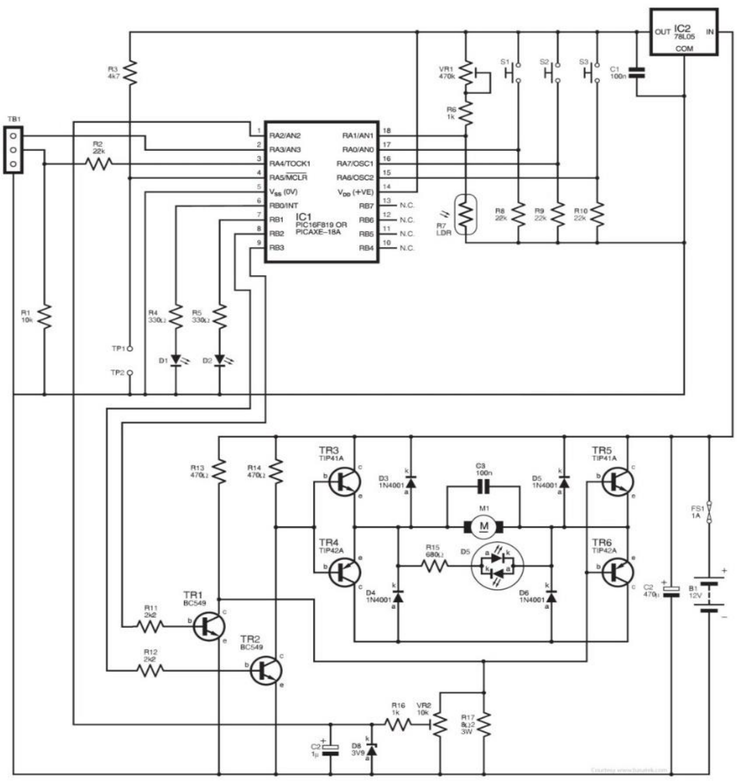
The microcontroller is a well-known Microchip PIC16F819 model. The oscillating frequency was taken into consideration when choosing the component because most microcontroller design systems employ this frequency.

3.3 Analysis of the Design

To operate the complete system, a PIC microcontroller and a straightforward H-bridge motor control circuit are needed in the design. In order to bias the ICI pin 3 to a fixed logic level, resistors R1 and R2 are used. Below is a picture of the designed circuit schematic. We make sure that the various circuit parts are designed independently and then coupled together to make it easier to repair any errors that may occur while designing the tracker.

Figure 5.0: The Designed Circuit Diagram of the Solar Tracker

Fig. 5.0Circuit Design of the Solar Tracking System



3.3.1 Solar Tracker Basic System Components Used for Construction

The following parts/materials make up the construction of a solar tracker for the purposes of designing the prototype; A conventional resistor with a color band, solar panels, a PIC16F84 microcontroller, and in this project, resistors were utilized to limit the amount of current that could pass through the circuit. a transistor, a "T0 220" voltage regulator, and a capacitor between 22 and 25 volts.

4.0 CONSTRUCTION PROCEDURES

The building and implementation were finished. These steps are listed, in part.

- Schematic/layout diagram creation;
- Printed circuit board construction;
- Mechanical assembly

4.1 Forming of Printed Circuit Board

The "Dip Trace" program, which is free to download from www.diptrace.com, was used to create the project's PCBs and schematic design. To guarantee a desired result, cross-checking of footprints and design processes was required. A decent free programe that can be downloaded from the internet was used to build the schematic and layout diagram. The schematic and PCB layout was program then converted using the same program. In this project, the schematic and layout were designed using Dip Trace, a shareware program that was acquired from the "novarm" website. The schematic needed to be converted into a printed circuit board (PCB) after being designed.

4.2 Making of the Printed Circuit Board Using Press-n-Peel Transfer Film

The process of creating printed circuit boards only requires a few straightforward steps. As illustrated in the image below, the first step is to laser print the already created circuit image onto the dull side (emulsion) of Press-n-Peel Transfer Film, a unique sheet used to create printed circuit boards.

Figure 6.0 Printed Copy of Already Finished Design

The already printed picture on the Press-n-Peel is cut next, leaving a 14 border around the circuit image; after that, the board is cut to the appropriate size. Once this is finished, wash the copper-clad blank board. Use steel wool, detergent, or morning fresh to clean. Rinse the cleaned board with water and soap. Make certain to eliminate any soap traces.

4.2.1 Mechanical Assembly

The mechanical assembly's utilized motor already has a gearbox to provide a slow rotation that can rotate in either direction. The solar panel utilized in the design was intended for usage on a boat, in a car, or while camping. Its area was roughly 0.25 m2, or else the wind's force could be too much for the gears in the motor's gearbox to handle. To prevent the threads from rusting in the rain during the wet season, plastic sewer caps were put in the assembly's flange. U-bolts were used to secure the rotator to a diagonal support pipe. The diagonal support pipe's bottom was 5 inches away from the bottom of the rotator. The solar panel was fastened to the top support stand using brackets after the diagonal support stand had been mounted. To avoid slippage, flat rubber pieces were inserted between the bracket and the stand. A sheet metal screw was also used to hold the brackets in place. An aluminum angle that was fastened to the solar panel had holes bored through the center through the brackets. The placement of the holes on the panel will also affect where the bracket is placed along the top of the stand. [17]

4.2.2 Construction of the Solar Tracker

By soldering the microcontroller socket into place, the control circuit is built. The proper orientation of the electrolytic capacitors and semiconductors was carefully monitored during this operation. However, how the mechanical segment is put together depends on the particular specifications of the involved mechanics. The motor was a rotator for a television antenna. The system was designed to be detachable so that the solar panel and tracker could be removed during the rainy season, when there is less sunlight due to the rising rate of precipitation. 2 inch galvanized pipes were used during construction to support the tracker vertically. To stabilize it while doing this, one had to use wire support on the back pole [19].

4.2.3 Testing of the solar tracker

A few safety precautions were taken, with safety being the first concern, in order to test the completed project. The components, voltage, and current flow in the complete system were tested using a digital metre. After the solar tracking system was completed, power was applied to the control circuit using a 12V sealed lead acid battery without the microcontroller in place. This was done in order to prevent damage to the microcontroller in the event of a short circuit or an excessive voltage during the testing process. The supply rail was tested for proper operation using a digital voltmeter. This check served to establish that there existed +5V DC between the microcontroller's positive and GND points. The value could range from 4.85 to 5.15V, contingent upon the voltage regulator that is being utilized.

4.3 Operation of the solar tracker

When the Light Dependent Resistor detects or receives solar radiation, a microcontroller-controlled electronic circuit decodes the signal and instructs the motor to rotate either clockwise or anticlockwise depending on the location of the sun. In the end, this procedure causes the mechanical assembly's associated solar panel to rotate so that it faces the direction of the sun.

4.3.1 Sensitivity of Solar Tracker via Output

When the sensor is shaded from sunlight, the tracker will return to its initial location, demonstrating the tracker's sensitivity. However, the sensor will rotate in the direction of the light when it is exposed to light. It's intriguing to note once more that the tracker's output voltage increases with light intensity.

4.3.2 Advantages of the Designed Solar Tracker

The solar panel's efficiency can be best increased by the developed solar tracker's ability to track direct sun irradiation. Our constructed solar axis produces more energy than 30% more than fixed solar panels when compared to them.

5.0 EFFICIENCY OF THE DESIGNED SOLAR TRACKER AND DATA COLLECTION

For rural, non-electric villages in Nigeria, a single-axis solar tracker system design is suggested. Other rural locations throughout the world can use this system design. The solar tracker PV-based system is the first of its kind to be created and put into use for isolated places.

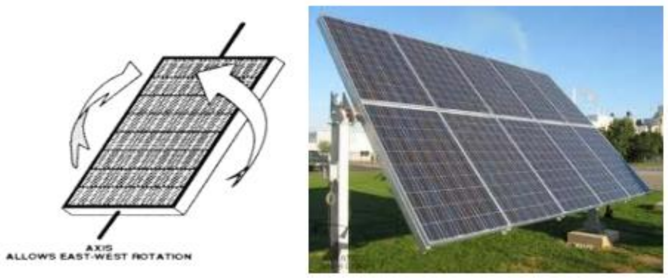


Figure 7: Single-Axis Solar Tracker

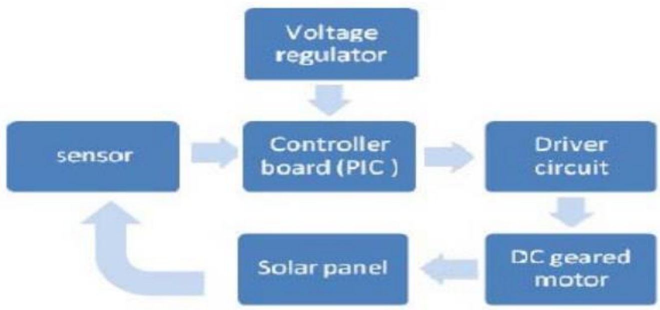


Figure 8: Block Diagram for Single-Axis Solar Tracker

5.1 Efficiency of Single-Axis Tracking System over Fixed Mount

The hourly readings from the solar tracker a single axis and stationary solar panels are shown below. Their graph was generated using MATLAB.

TABLE 1:
COMPARISON OF FIXED MOUNT WITH SINGLE-AXIS TRACKER SYSTEM

Hours	Static Panel			Solar Tracking (Single Axis)		
	V	mA	mW	V	mA	mW
08.00 AM	08.4	0.60	05.04	09.15	1.70	15.60
09.00 AM	08.5	1.17	09.94	09.45	1.78	16.86
10.00 AM	08.6	1.25	10.75	09.70	1.99	19.30
11.00 AM	09.7	1.82	17.65	09.85	2.38	23.44
12.00 PM	09.9	2.22	21.97	10.20	2.70	27.54
01.00 PM	10.3	2.56	26.36	10.80	3.20	34.29
02.00 PM	10.5	2.97	31.18	10.70	3.05	32.68
03.00 PM	09.7	2.71	26.28	10.25	2.93	30.08
04.00 PM	08.6	2.50	21.5	09.80	2.63	25.77
05.00 PM	08.3	2.14	17.76	09.25	2.43	22.47
06.00 PM	08.1	1.43	11.58	08.75	1.87	16.40
Average Power			18.18			24.03

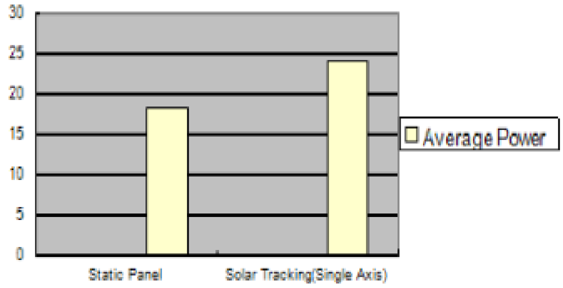


Table2: Power output for fixed mount Versus Single-Axis Tracker [20]

HOUR	POWER FOR FIXED MOUNT(mW)	POWER FOR SINGLE-AXIS(mW)
0800	20.664	62.403
0900	39.780	67.473
1000	44.176	77.212
1100	70.616	93.772
1200	88.110	110.430
1300	104.960	137.160
1400	125.334	130.754
1500	105.342	120.335
1600	86.172	103.096
1700	70.620	89.910
1800	46.494	65.625

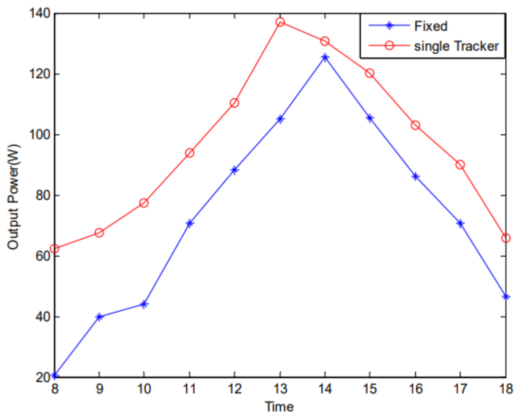


Figure 9: Simulation Result for Fixed Mount and Designed Single-Axis Solar Tracker System

6.0 CONCLUSION

After the prototype solar tracker system with solar panels and charge controllers was designed and built. The project was developed and built with efficient performance at a low cost. With the project's completion, we can state that the solar tracker is being used to build a new method of efficiently utilizing the energy of the sun's light in order to enhance the output voltage. And when there is an emergency power loss, users can be assured of power for use in lighting applications immediately, eliminating or lessening the effect of a total blackout. Additionally, a solar tracker can be permanently employed as a backup power source for an extended period of time.

Finally, for harnessing solar energy, this project has outperformed the typical solar panel (installed permanently). Because the tracker can rotate and follow direct sunlight, which accounts for over 90% of the output voltage, the research work's findings indicate that the proposed solar tracker can increase the efficiency of the system by over 30%.

7.0 RECOMMENDATIONS

The development of solar tracking systems has a lot of space for improvement because of the rising need for electricity consumption on a global scale. The project that has so far been built is a miniature tracker that shows how big-scale scale integration functions. Due to its pollution-free nature, solar tracker technology and the need for improvement in renewable energy sources should both receive top priority.

As predicted projections suggest, tracking boosts system efficiency by roughly 30%, it should be put into use to ensure adequate and inexpensive electric power supply to the world's remote and coastal regions.

Plans should be made towards full-scale implementation and use of solar power systems for electrification purposes, as this would allow for the diversification of the weekly fueling budget to other more pressing sectors.

The government should also boost research into battery efficiency to lower costs associated with production and facilitate the development of solar cells for the best output delivery. Additionally, there needs to be an awareness campaign to promote the use of renewable energy sources like solar energy, which will help to reduce the high levels of environmental pollution currently present that have a negative impact on human psychology and the carbon (IV) emissions that contribute to the ozone layer's thinning.

Declaration of Non-Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

Data Availability Statement

The sources of the data used in this research have been duly referenced in the available literature.

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