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DEVELOPMENT OF A SOLAR-POWERED AUDIBLE BIRD REPELLER SYSTEM FOR DISTRIBUTION SYSTEM IN LAGOS STATE, NIGERIA

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ABSTRACT
Bird activities on power distribution networks in Lagos State, Nigeria causes frequent power outages, equipment degradation, and substantial economic losses through electrocution, nesting, contamination, and interference with conductors and poles. This paper presents the development of a cost-effective, solar-powered, firmware-controlled audible bird repeller system designed to clear the overhead power corridor. The system architecture integrates a Passive Infrared (PIR) sensor for motion detection, an ATmega328P microcontroller, a 12 VDC wailing siren for auditory deterrence, and an MG995 servo-driven moving bar for physical displacement. Off-grid energy sustainability is achieved using an 18 V, 20 W solar panel, a 12 V 7 Ah rechargeable battery, an LM2596 DC-DC buck converter for optimal charge regulation, and a transistor-driven forced-air cooling system for thermal management. Following schematic capture and validation in Proteus software, the system was fabricated on custom Printed Circuit Boards (PCBs) and field-tested. Simulation results confirmed precise circuit triggering, establishing a 10.0 VDC output to the alarm loop upon sensor activation. Field evaluations verified that the device reliably detects avian targets within a 7-meter range at a 120° viewing angle, initiating synchronized auditory and mechanical deterrence for approximately 20 seconds per detection cycle. Empirical field testing on both ground levels and active utility poles demonstrated the effectiveness of the device. This sensor-driven, automated alternative to traditional mechanical fixtures offers a scalable solution to minimise avian-induced outages and improve supply reliability in tropical urban distribution networks.

Keywords: Bird repeller, Solar-powered system, Power distribution outages, PIR sensor, Audible deterrence

INTRODUCTION

Electric distribution systems deliver electricity to residential and industrial users, but birds pose a significant challenge to reliability. Bird-related incidents commonly cause outages through various mechanisms (Feng *et al*., 2022; Yilmaz *et al*., 2026). Birds use distribution infrastructures for perching, nesting, and resting (Lui and Li, 2024). Millions of birds die annually from electrocution or related activities on power lines worldwide (Gilad *et al*., 2024; Durgapersad, 2025).

Electrocution occurs when birds contact two-phase conductors or a conductor and ground wire, with risk increasing with body size. Large flocks cause contamination and bridging of energised wires. Flocks taking off simultaneously can make lines sag or swing. Cavity-nesting species damage wooden poles and equipment, attracting predators and increasing collision risks. These activities lead to outages, wildfire ignitions, and economic losses (Akanni *et al*., 2024; Biasotto, 2021; Feng *et al*., 2022; Yilmaz *et al*., 2026).

In Lagos State, Nigeria, 1,959 animal-related (including bird) faults were recorded over three to four years on the Eko and Ikeja networks (Akanni *et al*., 2022). Animal-induced faults occur at an average of 44.5 incidents per month on the Lagos distribution network (Akanni *et al*., 2023).

Mitigation strategies in literature include retrofitting poles, undergrounding cables, bird diverters, insulation of jumpers, nesting platforms, flappers, perch deterrents, and deflectors (Biasotto *et al*., 2021; Pruteanu, 2023; Sielicki *et al*., 2020; Silva *et al*., 2022). Most are mechanically controlled.

Several solar-powered bird repeller systems have been documented in the literature; however, the majority of these devices are designed primarily for agricultural applications. Furthermore, most existing systems rely solely on acoustic or visual scaring mechanisms, lacking a dynamic mechanical component—such as a servo-controlled moving bar—to provide physical deterrence (Ajibodu and Ojo, 2024; Chavda *et al*., 2023; Mano and Sandhiya, 2024; Mohana *et al*., 2024).

This paper develops a cost-effective solar-powered, firmware-controlled, sensor-based audible bird repeller system for continuous mitigation on distribution networks. The system uses a PIR sensor to detect birds and simultaneously triggers a sound generator and a servo-driven moving bar to displace birds from the power corridor.

MATERIALS AND METHODS

Methods

The system was conceptualised via the block diagram in Fig. 1. The schematic diagram (Fig. 2) was designed and simulated in Proteus software as shown in Fig. 3, then used to fabricate the Printed Circuit Boards (PCBs) for the main and servo control systems shown in Figs 4 and 5, respectively. Servo motor movement is directed by firmware (see appendix 1) embedded in the microcontroller.

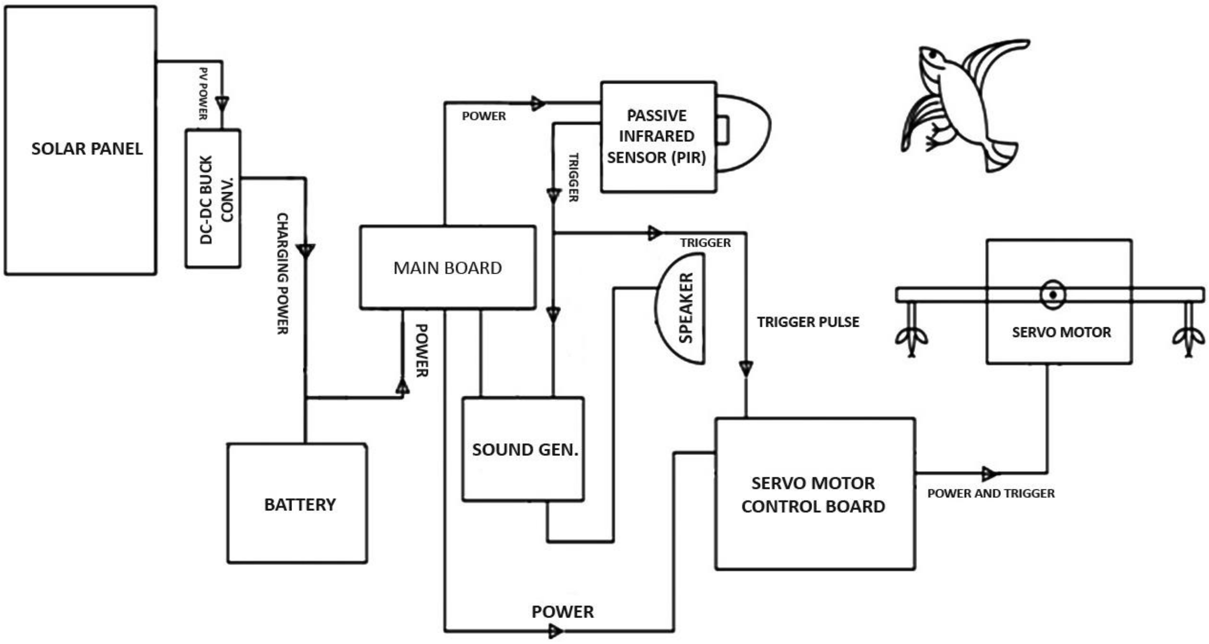

Figure 1: Block diagram of a solar-powered audible bird repeller system

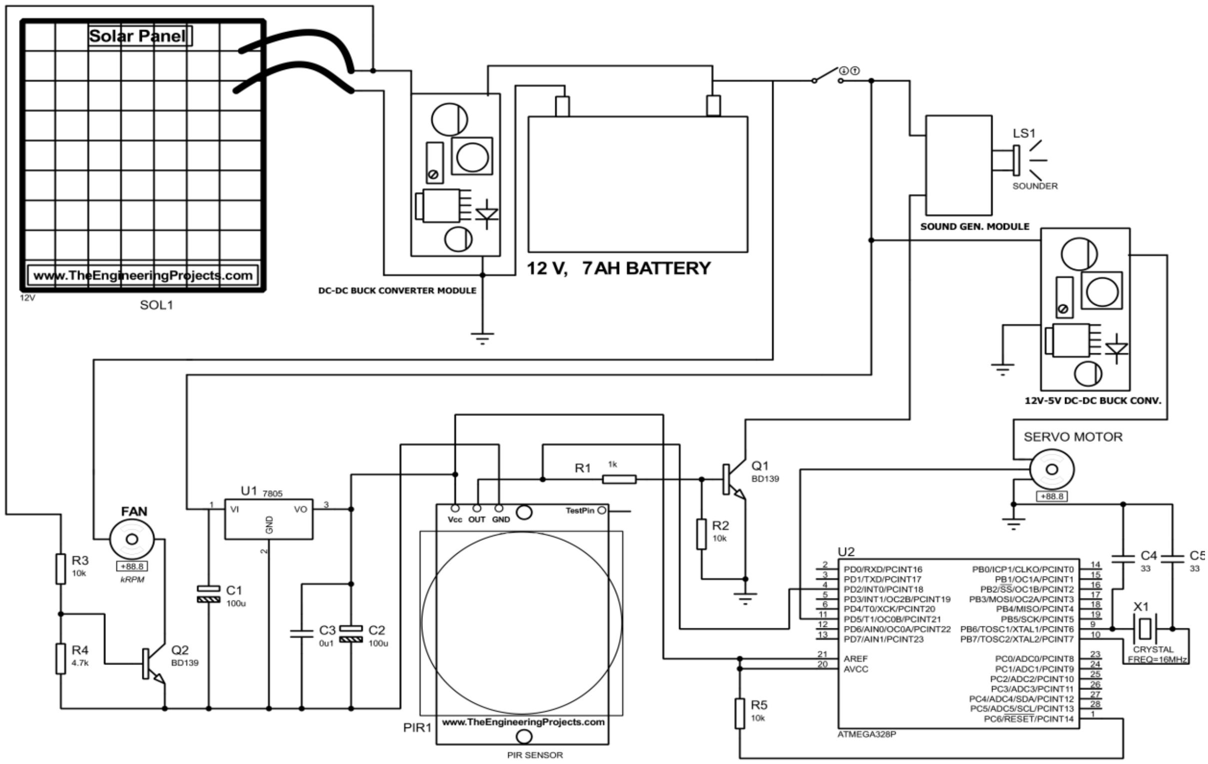

Figure 2: Schematic diagram of solar-powered audible bird repeller system

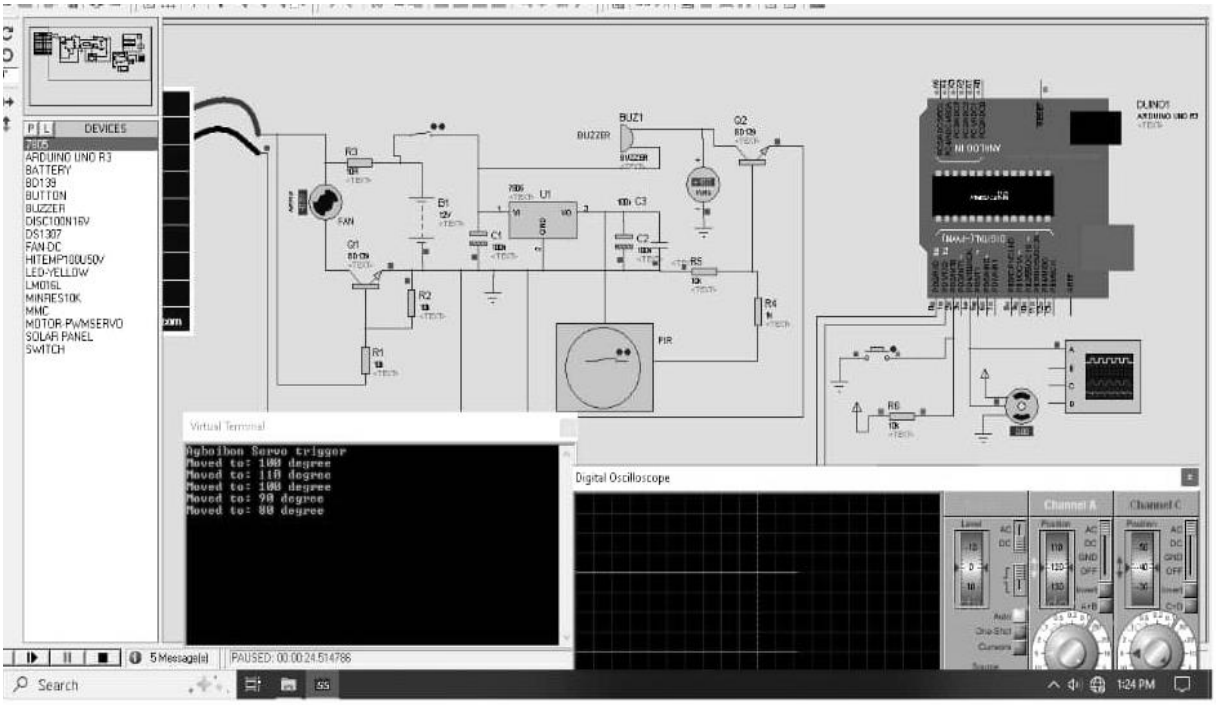

Figure 3: Screenshot of the simulation using proteus software

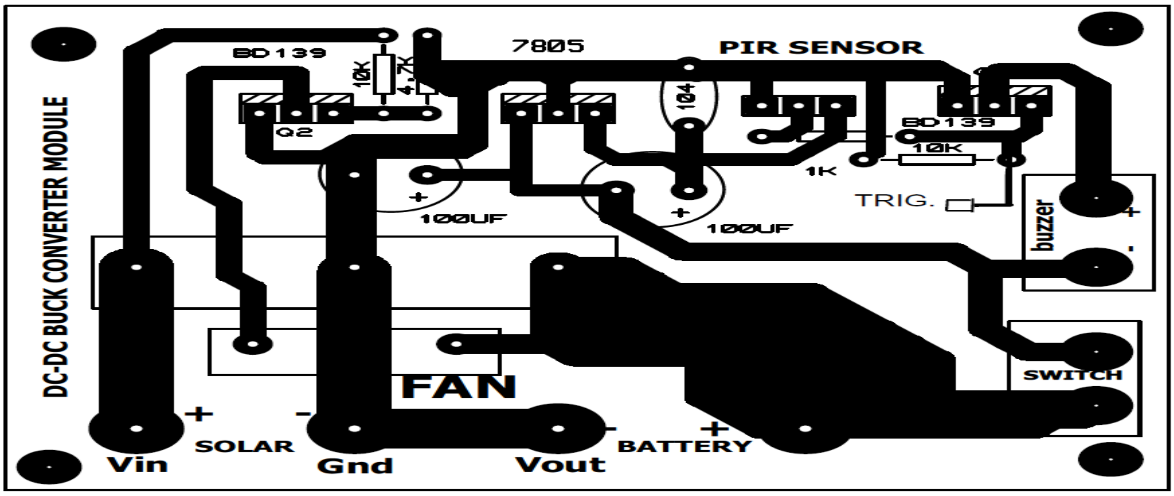

Figure 4: PCB of a solar-powered audible bird repeller system

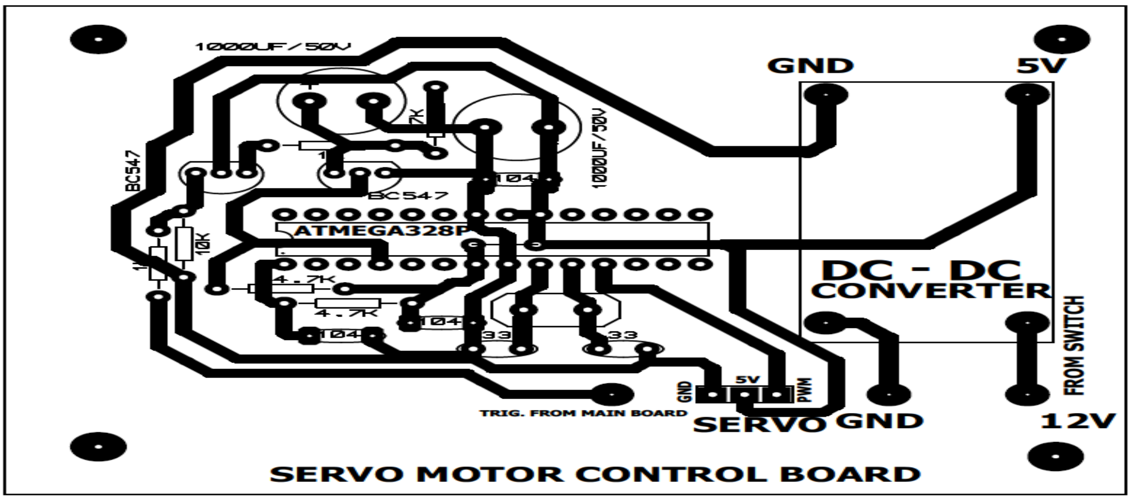

Figure 5: PCB of the servo motor control of solar-powered audible bird repeller system

Materials

Key components include: Passive Infrared (PIR) sensor, ATmega328P microcontroller, MG995 servo motor, forced-air cooling system, power supply (20 W solar panel and 12 V 7 Ah battery), LM2596 adjustable DC-DC buck converter, wailing siren, and a moving bar (short steel rule).

Passive Infrared Sensor (PIR)

The PIR sensor detects infrared radiation from moving objects (animals/humans) within range. It operates on 5 VDC with low power consumption and has three pins: Pin 1 to +5 V, Pin 2 (output) to the amplifier, and Pin 3 to ground via resistor.

ATmega328P Microcontroller

This low-cost, low-power 8-bit AVR microcontroller (28 pins, 32 KB flash, 1.8–5.5 V operation) was selected for its performance and suitability in embedded applications.

Servo Motor

The MG995 servo motor offers 180° rotation, lightweight design, and easy connection. It operates at 4.8–6.6 V.

Forced-air Cooling System

This comprises a 12 VDC low-power extractor fan, NPN transistor Q2 in common-emitter configuration, and bias resistors. It removes heat from the enclosure, particularly during daytime charging.

Power Supply System

The system uses an 18 V, 1 A, 20 W solar panel and a 12 V 7 Ah rechargeable battery for continuous operation with minimal daytime power demand and night time backup.

LM2596 Adjustable Switching Buck Converter Module

This step-down regulator (3–40 V input, 1.23–37 V output, up to 3 A) serves as a charge controller to prevent battery overcharging while providing excellent regulation.

Wailing Siren

A 12 VDC horn speaker, triggered via NPN transistor Q1 in common-emitter mode, produces a loud, scaring sound to displace birds.

Moving (Attached) Bar

A short steel rule attached to the servo motor creates mechanical movement to displace birds.

Principle of Operation

The inner view of the developed system is shown in Fig. 6. When a bird perches on the cross arm or lines, the PIR sensor detects a positive differential change and sends a signal through a 1 kΩ resistor and 10 kΩ divider to transistor Q1. This activates the wailing siren and sends a pulse to the ATmega328P, which drives the servo motor for ~20 seconds (per firmware). When the bird leaves, a negative signal turns off the siren and servo. A linear regulator steps down battery voltage to 5 V for the PIR. The buck converter regulates charging. The cooling fan activates during daylight via transistor Q2 and stops at dusk.

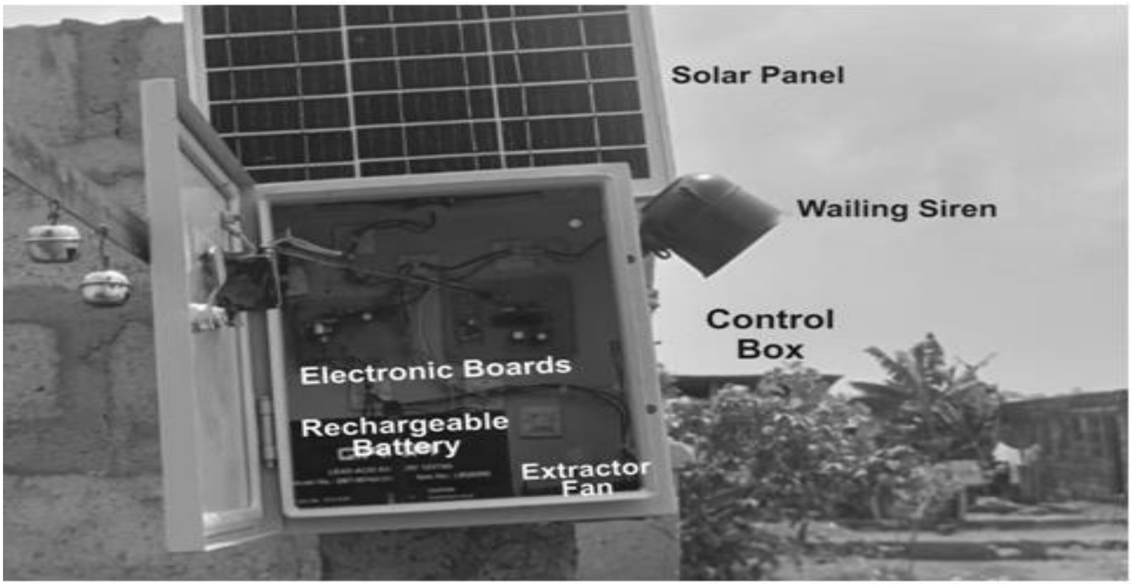

Figure 6: Inner views of the solar powered audible bird repeller system

Installation

The solar panel and enclosure are mounted on the distribution pole. The enclosure is placed in the safe zone with the PIR sensor facing upward toward the cross arm (maximum 7 m from the top). The solar panel must not obstruct the sensor's view.

RESULTS AND DISCUSSION

Simulation and Circuit Validation

The integration of the methods described in Section 2 resulted in a functional, dual-stage solar-powered bird repeller system. The hardware architecture relies on the synchronized operation of two primary modules: the main sensor board (housing the PIR sensor and buzzer alarm circuitry) and the servo control board (housing the ATmega328P microcontroller and its embedded firmware and the servo motor).

Prior to physical fabrication, the entire schematic was simulated using Proteus software to validate the system logic and voltage thresholds. As illustrated in the simulation interface (Fig. 3), introducing a high logic level to mimic PIR sensor activation immediately drove the base of the switching transistor into saturation. This validation test demonstrated that a steady 10.0 VDC was delivered across the buzzer alarm loop, confirming sufficient voltage to actuate the wailing siren under field conditions.

Concurrently, the simulation verified the firmware logic governing the mechanical displacement subsystem. Upon sensor triggering, the ATmega328P microcontroller immediately initiated a digital high output (Logic 1) to the servo motor control pin, represented in the Proteus oscilloscope display as a stable digital signal trace. The corresponding angular sweep of the attached mechanical bar—dictated by the embedded time-delay and directional routines—was successfully monitored and verified via the microcontroller's virtual serial communication port, confirming error-free firmware execution prior to physical implementation.

Hardware Realization and Field Deployment Test

Following successful simulation trials, the system was translated into physical hardware on custom-printed circuit boards (PCBs) and subjected to empirical field testing under two distinct operational scenarios.

The primary field test evaluated the device's functional response in an open-ground environment to isolate sensor sensitivity and target displacement. As shown in Fig. 7, when an avian target entered the 120^0 detection envelope within the 7 m range, the PIR sensor registered the positive differential infrared shift. The system responded dynamically by emitting a high-decibel audible alarm coupled with the rapid, sweeping motion of the servo-driven steel bar. This dual-sensory stimulus completely disrupted the bird's perching behavior, successfully forcing it into flight (marked by the black circle in Fig. 7).

Figure 7: Open-field test demonstrating successful avian flight response (highlighted by the black circle) upon system activation

The secondary field test assessed structural and environmental integration by mounting the completely enclosed, solar-powered apparatus directly onto a live electrical utility distribution pole (Fig. 8). The PIR sensor was oriented vertically toward the cross-arm zone to monitor critical high-voltage perching areas without interference from the solar panel's profile. During operation, the device demonstrated excellent environmental resilience. The forced-air cooling system regulated internal enclosure temperatures during peak daylight charging hours, while the 20 W solar and 7 Ah battery subsystem maintained an uninterrupted power supply. When activated on the pole, the combined acoustic output and automated physical sweeps proved highly effective at clearing the utility cross-arm corridor, confirming the device's viability as an active mitigation tool against animal-induced grid faults.

Figure 8: Field deployment of the solar-powered bird repeller system mounted directly onto an active overhead distribution pole corridor

CONCLUSION

This study successfully developed and evaluated a solar-powered, firmware-controlled audible bird repeller system to address the persistent challenge of avian-induced faults on the electricity distribution networks of Lagos State. By
merging electronic sensing with synchronized multi-sensory deterrence, the system provides an active alternative to passive mechanical deterrents.

Key performance indicators validated during the design and testing phases include:

1. **Circuit validation:** Proteus simulations confirmed robust firmware execution and reliable hardware logic, generating a stable 10.0 VDC digital signal to activate the alarm sub-circuits.
2. **Sensing and autonomy:** The hardware demonstrated an effective detection envelope of up to 7 meters with a 120° wide-angle view, maintaining autonomous 24 h operation powered by a 20 W solar array and battery backup.
3. **Operational efficacy:** Empirical field trials—conducted both in open-field settings and directly on distribution poles—confirmed that the dual-action response (12 VDC wailing siren and a 20 second servo-driven sweeping bar) were effective to handle the challenge of birds on the cross-arm zone.

The implementation of this automated, low-maintenance device along critical utility corridors holds significant potential for utility operators. By actively preventing perching, nesting, and bridging, the system can substantially lower the monthly average of 44.5 animal-induced distribution faults in Lagos State, reducing maintenance expenditures and improving overall grid reliability for consumers.

Conflict of interest: The authors declare no conflict of interest.

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APPENDIX 1

Firmware for the Servo Motor Operation

```
#include <Servo.h>

Servo myservo;  // create servo object to control a servo
#define servoPin 5 //~
#define triggerPin 2

int angle = 90;    // initial angle  for servo
int angleStep =10;
const int minAngle = 70;
const int maxAngle = 110;

void setup() {

Serial.begin(9600);          //  setup serial
myservo.attach(servoPin);  // attaches the servo on pin 5 to the servo object
pinMode(triggerPin,INPUT_PULLUP);
Serial.println("Agboibon Servo trigger ");
}

void loop() {
while(digitalRead(triggerPin) == LOW){
  // change the angle for next time through the loop:
angle = angle + angleStep;

   // reverse the direction of the moving at the ends of the angle:
if (angle <= minAngle || angle >= maxAngle) {
angleStep = -angleStep;
   }
myservo.write(angle); // move the servo to desired angle
Serial.print("Moved to: ");
Serial.print(angle);   // print the angle
Serial.println(" degree");
delay(50); // waits for the servo to get there
  }// while

}//loop
```