ELECTRICAL TRANSMISSION LINE INSPECTION ROBOT

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Abstract

This paper reviews the use of Electrical Transmission Line Inspection Robots (ETLIRs) from to , emphasizing their importance in detecting faults early and ensuring efficient power transmission. It explores climbing, flying, and hybrid (climbing-flying) robots, highlighting their structures, operations, and limitations. While climbing robots offer proximity for reliable data, challenges like landing and obstacle avoidance persist. Hybrid robots show promise by combining climbing and flying capabilities. The paper also discusses challenges like power supply, obstacle detection, and control systems, and suggests future research directions such as enhancing battery capacity, improving fault detection, addressing electromagnetic shielding, implementing de-icing mechanisms, and developing advanced control techniques for wind disturbances.

Keywords:

1. Introduction

Robots in manufacturing have boosted productivity and product quality, particularly in high-labor-cost countries, sustaining the viability of manufacturing industries. Today, a substantial portion of market products undergo assembly or handling by robotic systems.

1.1. INTRODUCTION TO ROBOTICS:

Robotics enhances human comfort by handling menial tasks, allowing focus on intellectual pursuits. This optimization frees us to innovate and improve machine efficiency, enhancing overall quality of life. Robotics spans disciplines like control, AI, machine vision, and modeling, with applications across electronics, mechanical engineering, and computer science. Robots, inspired by nature, serve diverse functions from bomb detection to human-like tasks, guided by principles like Isaac's Three Laws of Robotics. While humanoid robots remain elusive, practical applications in industries like automotive and medical continue to grow, with over a million in operation globally.

1.2. HISTORY:

The electrical transmission line system transports electricity from generating stations to distribution centers. Overhead lines are more common globally due to lower costs. Regular inspections are crucial for detecting faults early and preventing outages. Traditional manual inspections are risky and slow. Ground-based telescopic inspections offer safety but lack efficiency. Ground-based robotic systems, like Quanta Services' Line Master, provide precise inspections but are slow and limited in maneuverability. Helicopter inspections are faster but expensive. Electrical transmission line inspection robots (ETLIRs) offer a cost-effective and safer alternative, though challenges include obstacle navigation and environmental factors like snow and wind. This paper reviews ETLIR design and development from 2008 to 2019, highlighting advancements in inspection methodologies.

1.2.1. WHAT IS A ROBOT?

Robotics encompasses the design, construction, and operation of re-programmable manipulators for various

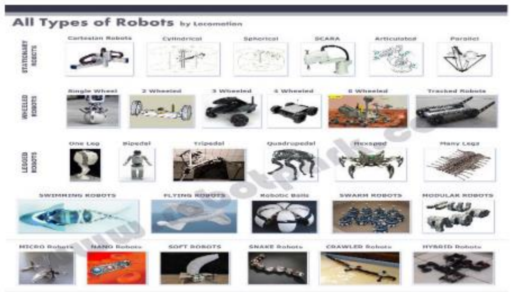

Fig.1.1: Types of robots

tasks. It integrates electronics, engineering, mechanics, mechatronics, and software. Robots are classified as autonomous or remote-controlled, with firefighting robots primarily focusing on remote control. Human gesture communication enhances machine intuitiveness. Issac Asimov's Laws of Robotics include rules prioritizing human safety and robot self-preservation.

1.3. SCHEMATIC DIAGRAM & EXPLANATION:

We gathered all the equipment and parts which are required for making a prototype The methodology we followed as follows.

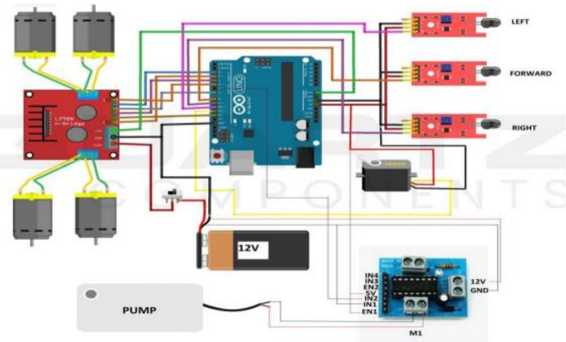

Fig.1.2: Schematic diagram

The schematic diagram consists of an ESP8266 microcontroller, Motor DriverL298D, Wi-Fi Module, three flame sensors, a pump, and two DC motors, which are interconnected. • Pin 0 and Pin 1 are connected to RX and TX of B.

• Pin 3 of Arduino is connected to the ENA of the L298D motor driver.
• Similarly, Pin 4, Pin 5, and Pin 6 are connected to IN 2, IN 1, and ENA B respectively.
• Pin 7, and Pin 8 are connected to IN3 and IN 4 respectively.
• SENSA, SENSB, and GND are inter-connected
• The output pins OUT 1 and OUT 2(PIN 3 and PIN 4) are connected to one motor.
• OUT 3 and OUT 4(PIN 13 and PIN 14) are connected to the other motor.
• +5V is given to VCC and +12V is given to GND.
• After the connections are made dump the code from Arduino IDE into the ESP Module.

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2. Experimentation

2.1. Flowchart

START

LITERATURE REVIEW

IDEATION And SELECTION of ROBOT

PROCUREMENT And ASSEMBLY

MAKE a CODE And RUN IT

RESULT And CONCLUSION

Fig. 2.1: Flow chart

2.2. Component Selection and Procurement:

The ETLIR construction process begins with a thorough examination of project specifications and technical needs to determine required components. Research identifies potential suppliers based on factors like cost, quality, and compatibility. Comparative analysis informs supplier selection, prioritizing reliability and responsiveness. Orders are placed with attention to lead times and logistics, with ongoing communication to address any issues. This meticulous procurement process streamlines component acquisition, ensuring timely construction and assembly within project deadlines.

2.3. Assembly and Integration:

Upon component receipt, a thorough inspection ensures adherence to quality standards. Each component undergoes scrutiny for defects. Assembly follows manufacturer instructions, integrating parts systematically. Prior to integration, individual component and subsystem testing occurs to ensure functionality. Integration focuses on alignment and connectivity, crucial for performance. Adherence to assembly instructions minimizes errors. Regular checks maintain assembly integrity. This meticulous approach ensures precise assembly and integration of the ETLIR, guaranteeing effective task performance.

2.4. Software Development and Configuration:

In software development for the ETLIR, meticulous attention ensures seamless management of movement, sensor data acquisition, and autonomous navigation. This involves configuring sensor settings, communication protocols, and fault detection algorithms. Movement control software interprets user commands for precise actuator and motor instructions. Sensor data acquisition software collects data reliably from integrated sensors. Autonomous navigation algorithms interpret sensor data for optimal path planning. Fine-tuning sensor settings enhances performance. Communication protocols enable interaction with external systems. Fault detection algorithms monitor system behavior and trigger responses to anomalies. User interface features provide intuitive remote operation and monitoring. Rigorous testing ensures software reliability and functionality. Through these processes, the ETLIR's software ecosystem is optimized for precise control, reliable data acquisition, autonomous navigation, fault detection, and remote operation, enhancing overall performance and usability.

2.5. Testing and Validation:

After ETLIR assembly, thorough testing is crucial to assess performance and reliability across various parameters. Functional tests ensure subsystem operation, including navigation and sensor data acquisition. These tests simulate scenarios to evaluate the robot's responses. Navigation tests assess accuracy and safety on predefined routes. Sensor tests validate readings under diverse conditions. Field tests in urban, rural, and adverse weather environments evaluate adaptability and performance. Data collection evaluates inspection efficiency, fault detection accuracy, and system reliability. Comprehensive testing ensures the ETLIR meets project objectives and can address deficiencies through design refinements, enhancing overall performance and reliability.

2.6. Documentation and Training:

The ETLIR assembly involves constructing the frame, integrating electronics, and attaching the end effector for optimal functionality. Mechanical components are carefully selected and installed according to schematics, including motors and actuators with specified ratings. Frame materials are chosen for durability. Electronics integration includes a control board, sensors, and power supply. Software configurations ensure compatibility, establish communication protocols, and implement safety features. Operator training covers safe operation, programming, and emergency protocols, with hands-on sessions for equipment familiarization. Maintenance personnel receive training on upkeep and troubleshooting. User manuals provide detailed guidance on assembly, operation, and maintenance procedures for safe and effective use.

3. Methodology

3.1 Nomenclature

3.1.1 Actuators:

The actuator is a device that actuates the movement of the robot joints. And there are several different types of actuators in common use for robotics they are.

- Synchronous motor
- Stepper motor
- AC servo motor
- Brushed DC servo motor
- Brushless DC servo motor
- Hydraulic actuators

The above-mentioned types of actuators are used to initialize the operation in the robot, and they are shown in the below-given figure.

Fig.3.1 Types of motors

3.1.2. DC motor with gear:

This yellow plastic gear motor wheel is great for robotics projects, especially for robotic cars and line-tracing robots. It measures approximately 2.5" long, 0.85" wide, and 0.7" thick, with mounting flexibility on either side. Operating best between 4V to 7V (recommended 6V), it provides good torque at 5V with a 1:48 ratio.

Specification:

Motor Specifications
Operating voltage: 3V ~ 6V DC (recommended value 5V)
Maximum torque: 800g.cm
Speed without load: 90±10rpm.
Reduction ratio: 1:48
No Load current: 190mA(max.250mA)
Stall Current: ~1A.
Strong anti-interference on this motor keeps it safe around microcontrollers.

3.1.3. DC Motors

DC motors convert electrical energy into mechanical energy using magnetic fields generated by electrical currents. This powers the rotation of a rotor fixed within the output shaft. Output torque and speed depend on electrical input and motor design.

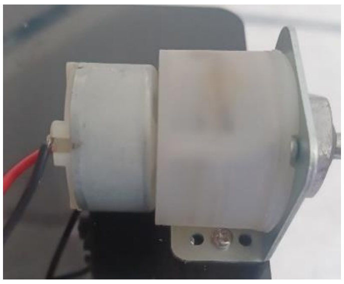

Fig.3.2: DC motor

3.1.4. MOTOR DRIVER (L298N):

Motor drivers interface motors with control circuits, typically utilizing H-bridge circuits enabling bidirectional voltage flow for motor rotation. The L298N Motor Driver Module is a high-power driver for DC and Stepper Motors, comprising an L298 motor driver IC and a 78M05 5V regulator. It can control up to 4 DC motors or 2 with directional and speed control. The 78M05 regulator powers internal circuitry if the supply is ≤12V, providing 5V output for microcontrollers. ENA & ENB control motor speed, while IN1& IN2 and IN3 & IN4 control direction. The L293D IC receives signals from the microprocessor, transmitting to the motors. Motors convert electrical energy into mechanical energy, facilitated by motor drivers. Various types include DC, stepper, and servo motors, each serving different purposes in automatic systems.

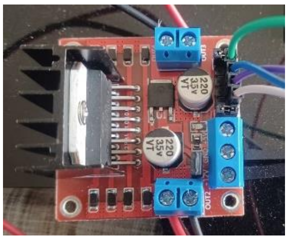

Fig.3.3: Motor driver

3.1.5. L298N Motor Driver Interfacing with ESP8266 Microcontroller:

The motor driver receives signals from the microprocessor and transmits them to the motors. It has two voltage pins (VCC1 and VCC2), one for powering the motor driver and the other for applying voltage to the motor. The motor IC toggles the output signal according to the input wave from the microprocessor.

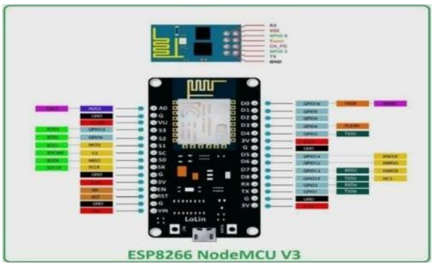

Fig.3.4: L298N Interfacing with ESP8266 Microcontroller

The H-bridge circuit comprises four switches forming an "H" shape to enable/disable the supply.

3.1.6. WHEELS:

U-groove wheels, also known as track wheels, are commonly used for linear motion. Featuring a U-shaped groove, these wheels traverse tracks or rails with stability and minimal lateral movement. Crafted from materials like steel, aluminum, wood, or plastic, they serve various industries including manufacturing, material handling, robotics, and transportation.

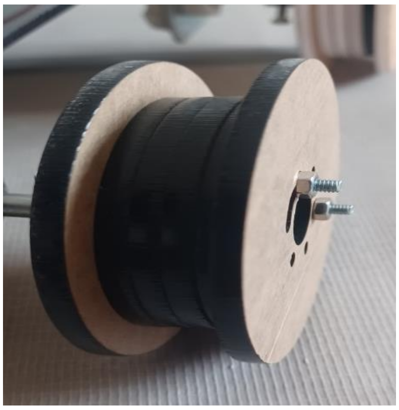

Fig.3.5: Wheel

They are essential for sliding doors, gates, and conveyor systems, providing smooth transportation along predetermined paths. U-groove wheels offer adaptable and reliable solutions for tasks requiring accurate linear motion.

3.1.7. Jumper wires:

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools to make it easy to change a circuit as needed.

3.1.8. BATTERY:

A Battery is a chemical device that stores electrical energy in the form of chemicals and by means of an electrochemical reaction, it converts the stored chemical energy into direct current (DC) electric energy. Basically, all electrochemical cells and batteries are classified into two types:

- Primary (non-rechargeable)
- Secondary (rechargeable)

3.1.9. Primary Batteries

Primary batteries serve as simple and convenient power sources for portable electronic and electrical devices such as lights, cameras, watches, and radios. They are not rechargeable and are discarded after use. These batteries are inexpensive, lightweight, and require little to no maintenance. Most primary batteries used domestically are single-cell types and typically cylindrical in shape.

- Alkaline Batteries.
- Lead-acid Batteries.
- Ni-Cd Battery.
- Ni-MH Battery.
- Li-Po battery.

3.1.10. Secondary Batteries:

A Secondary Battery, also known as a Rechargeable Battery, can be electrically recharged after discharge. By passing a current through the cells in the opposite direction of their discharge, the chemical status of the electrochemical cells can be restored to their original state.

- Lead – Acid Batteries
- Nickel – Cadmium Batteries
- Nickel – Metal Hydride Batteries
- Lithium – Ion Batteries

Fig.3.6: Ni-MH Batteries

3.1.11. Li-ion battery:

Lithium-ion (Li-ion) batteries are widely used in portable consumer electronics, electric vehicles, grid-scale energy storage, military, and aerospace applications. They boast high energy densities, low self-discharge, and no memory effect. Variants like lithium polymer ($LiCoO_2$ cathode) and lithium iron phosphate ($LiFePO_4$) cater to specific needs. M. Stanley Whittingham laid the foundation for Li-ion batteries in the 1970s, with subsequent developments by John Goodenough and Akira Yoshino leading to the modern Li-ion battery. Safety concerns prompted research into non-flammable electrolytes, including aqueous, ceramic, polymer, and ionic liquid-based solutions.

Fig.3.7: Lithium-ion Battery

Performance metrics include specific energy density (100-250 W·h/kg), volumetric energy density (250-680 W·h/L), and specific power density (300-1500 W/kg). Li-ion batteries find diverse applications due to their versatility and are favored for energy storage and portable power solutions.

3.2 Coding

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
```

```
#include<Servo.h>
const char *ssid = "Survelliance";
const char *password = "123456789";
int s1=70,s2=90;
Servo servo1;
ESP8266WebServer server(80);
String page =""; //For the Web Server
String page2="";  //For updating Status of robot
int sensor=10;
String mstr;
void setup() {
page="<center><h1> chitti the robot</h1><body><p><a
href=\"F\"><button>forward</button></a></p><p><center><a
href=\"B\"><button>backward</button></a></p><center><p><a
href=\"R\"><button>right</button></a></p><center><p><a
href=\"L\"><button>left</button></a></p><p><center><a
href=\"S\"><button>Stop</button></a></p><p><a
href=\"b\"><button>PUMP_ON</button></a></p><p><a
href=\"c\"><button>PUMP_OFF</button></a></p></body><p><a
href=\"a\"><button>Servo_sweep</button></a></p>";
delay(1000);
pinMode(D2,OUTPUT);
pinMode(D3,OUTPUT);
pinMode(D4,OUTPUT);
pinMode(D5, OUTPUT);   // inputs for motor 1
pinMode(D6,OUTPUT);
pinMode(D7,OUTPUT);    // inputs for motor 2
pinMode(D8,OUTPUT);
pinMode(LED_BUILTIN,OUTPUT);  // For status of WiFi connection
digitalWrite(D5,LOW);
digitalWrite(D6,LOW);
digitalWrite(D7,LOW);
digitalWrite(D8,LOW);
Serial.begin(115200);
Serial.println();
Serial.print("Configuring access point…");
WiFi.softAP(ssid, password);
IPAddress myIP = WiFi.softAPIP();
Serial.print("AP IP address: ");
Serial.println(myIP);
servo1.attach(D2);
server.begin();
Serial.println("HTTP server started");
  server.on("/", webpage);
  server.on("/F",Forward);
```

```
 server.on("/B",Backward);
 server.on("/L",Left);
 server.on("/R",Right);
 server.on("/S",stop1);
 server.on("/a",servo_sweep);
 delay(200);
 server.begin();
 Serial.println("Web server started!");
}
void loop() {
//mstr=String(sensor);
server.handleClient();
//server.send(200,"text/plain",mstr);
}
void webpage()
{
server.send(200, "text/html", page+page2);
}
void Forward()
 {
   //analogWrite(D3,60);
   //analogWrite(D4,80);
   digitalWrite(D5,HIGH);
   digitalWrite(D6,LOW);
   digitalWrite(D7,HIGH);
   digitalWrite(D8,LOW);
   Serial.print('F');
   page2="<center><p> Robot Status : Forward </p></center>";
   server.send(200,"text/html", page+page2);
   delay(200);
  }
 void Left()
  {
   page2="<center><p> Robot Status : Left</p></center>";
   server.send(200,"text/html",page+page2);
 //  analogWrite(D3,s1);
 //  analogWrite(D4,s2);
   digitalWrite(D5,LOW);
   digitalWrite(D6,LOW);
   digitalWrite(D7,HIGH);
   digitalWrite(D8,LOW);
   delay(200);
   Serial.print('L');
  }
 void Right()
```

```
 {
  //analogWrite(D3,s1);
  //analogWrite(D4,s2);
  page2="<center><p> Robot Status : Right</p></center>";
  server.send(200,"text/html",page+page2);
  digitalWrite(D5,HIGH);
  digitalWrite(D6,LOW);
  digitalWrite(D7,LOW);
  digitalWrite(D8,LOW);
  delay(200);
  Serial.print('R');
 }
 void Backward()
 {
  page2="<center><p> Robot Status : Backward</p></center>";
  server.send(200, "text/html", page+page2);
  //analogWrite(D3,s1);
  //analogWrite(D4,LOW);
  digitalWrite(D5,LOW);
  digitalWrite(D6,HIGH);
  digitalWrite(D7, LOW);
  digitalWrite(D8,HIGH);
  delay(200);
  Serial.print('B');
 }
 void stop1()
 {
   page2="<center><p> Robot Status : Stop</p></center>";
//  page3="<center><p> motor 2 Status : off</p></center>";
 server.send(200,"text/html",page+page2);
 //analogWrite(D3,s1);
  //analogWrite(D4,LOW);
  digitalWrite(D5,LOW);
  digitalWrite(D6,LOW);
  digitalWrite(D7,LOW);
  digitalWrite(D8,LOW);
  Serial.print('S');
 }
```

4. RESULTS AND DISCUSSION

4.1. RESULTS

Introducing electrical transmission inspection robots offers numerous advantages. By replacing human inspectors, robots reduce accidents and injuries in high-risk environments. They conduct inspections swiftly and consistently, improving fault detection and minimizing maintenance downtime. Equipped with sensors and cameras, robots gather extensive data on transmission line conditions, enabling issue identification and maintenance prediction.

Remote control capabilities allow inspections in remote or inaccessible areas without human presence. Though the initial investment is substantial, long-term cost savings result from reduced manual inspections and minimized unplanned downtime. Additionally, robot inspections reduce carbon emissions and wildlife disruption compared to helicopter or ground-based methods. Overall, electrical transmission inspection robots enhance safety, efficiency, and reliability, strengthening the electrical grid's resilience.

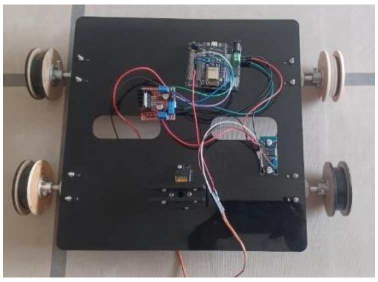

Fig.4.1: Top view of the Robot

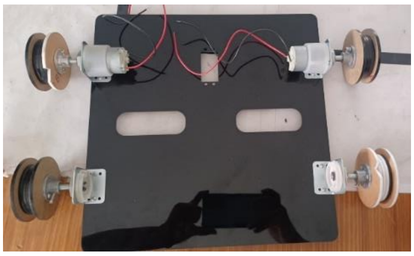

Fig.4.2: Bottom View of the Robot

4.2. DISCUSSION

An evaluation of a transmission line inspection robot typically involves a comprehensive analysis of its performance indicators, including speed, precision, and effectiveness in fault detection along the lines. This entails assessing metrics like the number of faults detected, instances of false positives, and missed detections, as well as comparing inspection time to traditional methods. It's crucial to address encountered limitations and suggest avenues for improvement. Discussion may explore implications for future robot deployment, focusing on safety, reliability, and cost-effectiveness enhancements.

5. CONCLUSION

In conclusion, the electrical transmission line inspection robot represents a groundbreaking innovation, offering numerous industry benefits. Its superior efficiency surpasses manual inspections, reducing operational costs and boosting productivity. Advanced sensors and AI algorithms ensure precise defect detection and hazard identification, enhancing safety standards and minimizing risks. Despite initial costs, its long-term cost-effectiveness, adaptability, and reliability make it invaluable to utilities. Its proactive data collection enables predictive maintenance strategies, enhancing infrastructure resilience. As a symbol of innovation, it sets the stage for smart technology to optimize infrastructure management and ensure uninterrupted electricity delivery worldwide.

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