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Design and Implementation of Energy Harvesting and Pollution Control System using Nano Tree

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Abstract: *In today's globalized society, energy consumption is a fundamental pillar of societal advancement and evolution. Street lighting applications consume a lot of electricity with the benefit of preventing accidents and ensuring the safety of pedestrians at night. The main considerations in the present field of technologies are automation, power consumption, and cost-effectiveness. Alongside, rapid industrialization and urbanization have resulted in an exponential increase in air pollution causing adverse effects on living beings and deterioration of fossil fuels. Hence, the use of regenerative sources of energy is crucial to facilitate the high power demand. The proposed system presents the development of a Nano tree using the Arduino board to collect renewable solar energy from the environment used for street light illumination by using sensors at minimum electrical energy consumption. The Nano tree can be used as an alternative to streetlights with the addition of LED strips along with an accumulation of gaseous pollutants. If the pollutant level exceeds the limit an alert will also be sent to the pollution control authority of the adjacent industry. The Nano Tree is the concept of an autonomous street light with atmospheric monitoring capability.*

Keywords: Nano Tree, Arduino board, Self-sustained street lights, Air monitoring

I. INTRODUCTION

The city's street lighting stands as a significant energy consumer, with advanced street lighting solutions offering substantial potential for reduction. These systems factor in utilization and occupancy to dynamically adjust light output, automatically distinguishing between automobiles, bicycles, and pedestrians[1]. Recent years have also witnessed a peak in industrial growth, accompanied by rising environmental contamination levels due to decreased industry oversight and auditing.

The research described in [2] employs the Internet of Things (IoT) to detect natural contaminants. It utilizes dual-purpose temperature and pH sensors to check water turbidity, temperature, and surrounding conditions. This system gathers and transmits data to the cloud to generate reports for addressing pollution. A significant obstacle in this setup involves processing vast volumes of data attributes in real-time. Considering the drawbacks, a compact edition designed for distant online monitoring of carbon monoxide (CO) and carbon dioxide (CO2) gases in outdoor settings is part of the Atmospheric Air Monitoring System detailed in [3]. This model transmits data to the server using the MQTT protocol, where it's stored by the data acquisition unit. The suggested approach necessitated users to remove the entire device from its deployment site, reprogram it, and then reinstall it, resulting in tedious efforts even for minor hardware-software adjustments.

Eventually, an integrated multi-server Internet of Things (IoT) network [4] has been established to manage solar trees effectively. This system consolidates security, surveillance, and pollution monitoring functions within a single power generation unit. The task of optimizing panel placement on the solar tree based on location coordinates posed a notable technological challenge. Furthermore, utilizing IoT technology, a solar-powered public lighting system equipped with anti-vandalism features was developed [5]. This system prioritizes power conservation, energy efficiency, automation, and intelligent operations alongside vandalism detection and monitoring. Future improvements involve integrating

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security cameras to enhance environmental security monitoring and further deter vandalism. The drawbacks of manual streetlight systems and IoT technology- developed systems based on automatic street lighting and control are overcome with the development of a system [6] comprising of Node MCU, LDR Sensor, IR Sensor, LCD Display, and Relay. The challenges faced by the proposed idea include the accuracy, reliability, and consistency of the information collected from IoT sensors

The development of a highly IoT-dependent smart city based on ESP8266 [7] uses IoT for accessing real-time street lighting data. It is a network that uses software, sensors, and connectivity to control and monitor data. Recent advances in solar-powered renewable energy harvesting systems represent a paradigm change toward sustainability and resilience, going beyond simple utility. In pursuit of this objective, the concept of a 'Nano tree' has arisen, featuring distributed power generation and utilization, thereby forming a network of self-sustained power generation units.

The idea of Nano Tree is a revolutionary concept embracing the principles of bio-mimicry, ingeniously employing solar panels as leaves to efficiently capture energy used for street light illumination by using sensors at minimum electrical energy consumption. Central to its design is a dual focus on power generation and the reduction of air pollution through the seamless integration of the IoT, which will be regularly updated to the public, and if the level exceeds the limit an alert will also be sent to the control board of the nearby industries. This concept is implemented through the Arduino IDE software tool, utilizing embedded C language.

II. METHODOLOGY

BLOCK DIAGRAM

The methodology and implementation section presents a detailed description of the design and development of the proposed energy harvesting and pollution control system. The block diagram consists of a power supply, Battery, and relay which form the power supply module of the proposed system in which the input voltage of a 12V power Supply is applied to the DC motor initially. The rotation of the DC motor in integration with solar panels helps in the generation of power from the solar panels which are applied as the input to the voltage regulator to provide enough voltage i.e. 5V to the ATMega328p microcontroller.

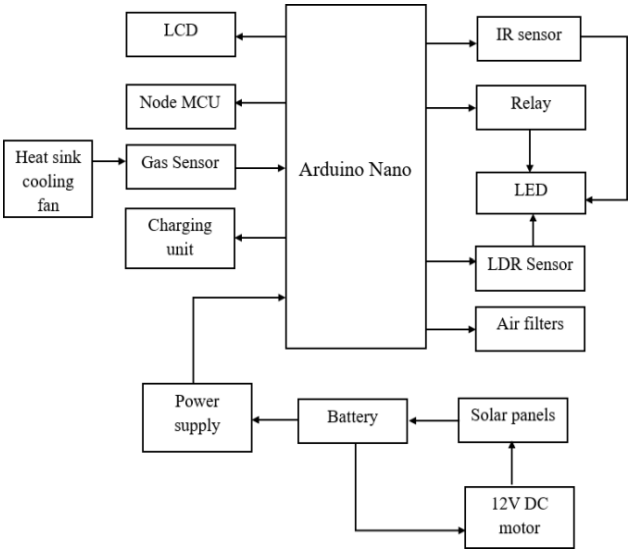

Fig 1 Block diagram

The block diagram of the proposed system consists of modules, including the energy harvesting module, LCD, and NodeMCU module The energy harvesting module consists of the relay, solar panels, LED, IR Sensors and LDR Sensors, power transmission lines, and switches. The solar panels generate the electricity which is supplied to the charging units. The relay ensures the device is charged to the prescribed power levels in a controlled and balanced manner with the indication of an LED glow. The pollution levels are increased manually beyond the threshold limit and

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the excess pollution levels are displayed on an LCD screen, providing real-time information to the user. The built-in GPS feature is used to determine the location of the Nano Tree. The NodeMCU module is used to send alert messages to nearby industries to collect carbon emissions for useful purposes.

FLOW DIAGRAM

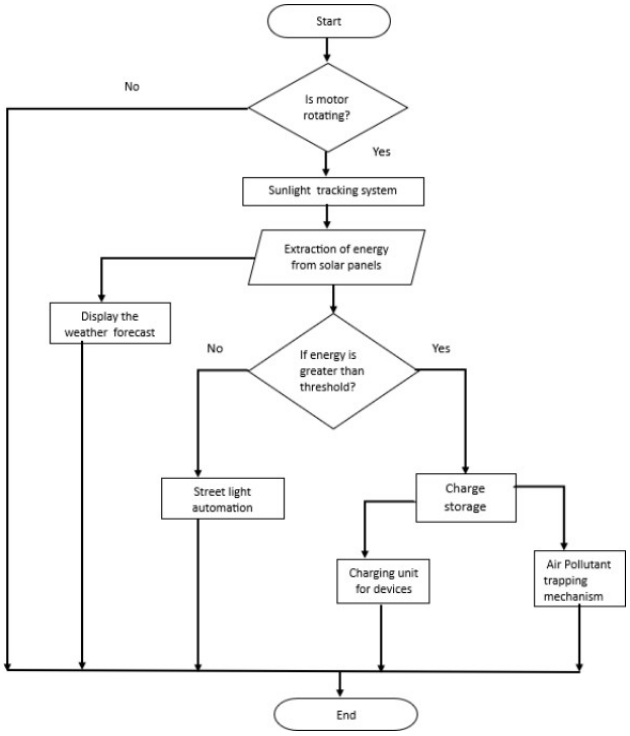

Fig 2 Flow Diagram

At the start of the flow chart, all the modules are initialized in the input and output ports as well as Node MCU modules are set up. As the system starts, the battery is used to turn on the 12V DC motor which helps in the solar panel rotation under the variation of sunlight intensity. A program is written for detecting the gaseous pollutants and conversion of solar energy into electricity which is uploaded to the microcontroller using Arduino IDE software. The collected solar energy is converted into suitable energy forms such as electricity required to power up the microcontroller. Meanwhile, the excess energy is stored in an energy reservoir which serves as charging points for electronic devices and it is also used in street light automation. The air filters and the MQ-135 gas sensors are placed in the central column of the Nano Tree to segregate the gaseous pollutants from oxygen and to detect or measure the gaseous pollutants from the environment. Also, the IR sensors at positioned at the base along with the LDR sensors beneath the solar panels to differentiate the variation in light intensity and to detect the object's movement. Once, the object is detected or light intensity variation is noticed, the LED strips beneath the solar panels get switched on. This acts as an alternative to street light automation.

The 20*4 LCD is placed on the central column of the Nano tree structure to determine the weather forecast details with the help of the DHT11 Temperature and humidity sensor. The LCD is also used for displaying the pollution levels if the threshold exceeds then NodeMCU ESP8266 alerts the nearby industries to collect the carbon emissions through built-in GPS features. Also, the solar tracker system uses the Arduino board, a DC motor, 2 LDR, and 2 resistors to rotate the solar panel towards the sun or a source of light. LDR is selected since it has no polarity, and easy to interface with the circuit, and is described by high spectral sensitivity. The DC motor is fixed to the structure that holds the solar panel. LDRs sense the amount of sunlight falling on them and accordingly rotate the solar panels in that direction.

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III. RESULTS

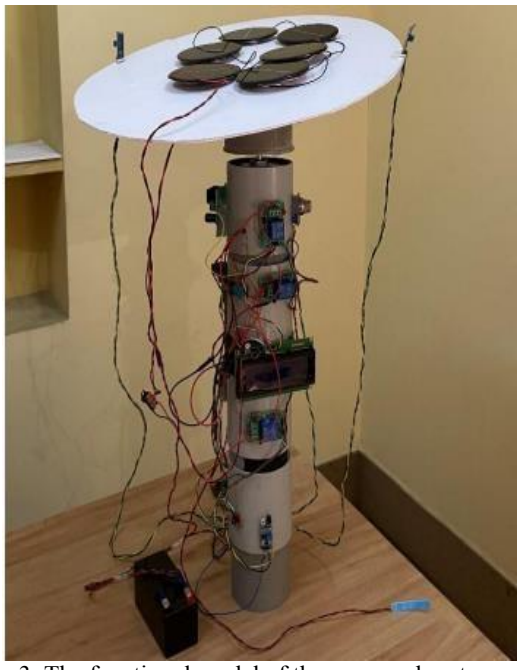

Fig 3: The functional model of the proposed system

The above figure hardware setup of the proposed system includes an Arduino Nano board, NodeMCU ESP8266, an IR Sensor, a 20x4 LCD, two LDR sensors, a 12V single relay, a L293D Motor Driver with IC, and a 9V battery. The Arduino Nano board serves as the central processing unit and controls the various components of the system. The NodeMCU ESP8266 module with the in-built GPS tracker is used for sending SMS alerts to nearby industries regarding the location and details of excess pollutants collected. The 20x4 LCD is used for displaying the appropriate weather forecast along with the indication of pollution in the surrounding environment. The 12V single-channel relay is used for sharing voltages across the charging units to ensure efficient power delivery. The battery provides power to the DC motor for the rotation of solar panels.

Fig 4. Weather forecast details and charging duration are shown on the LCD screen

Fig 4 shows the weather forecast details such as temperature and humidity displayed on an LCD screen depending on the intensity of light. The LCD screen also displays the appropriate charging duration.

Fig 5 shows the SMS received on the registered mobile number of the industry after the threshold pollutant level in the Nano Tree is exceeded. Each SMS contains information about the Nano Tree location, distance, and geo-location link. The details are displayed in a standardized format, allowing the control board members of the industry to identify the location and make the necessary provision for the collection. Fig 6 depicts the prototype of the Nano Tree under the Urban Infrastructure wherein the Nano street supplies power for the street light automation. Additionally, the Nano Tree shown in Fig 7 can also be used as an alternative for street lights in less crowded or remote areas thus effectively helping in cost reduction for installation of street lights.

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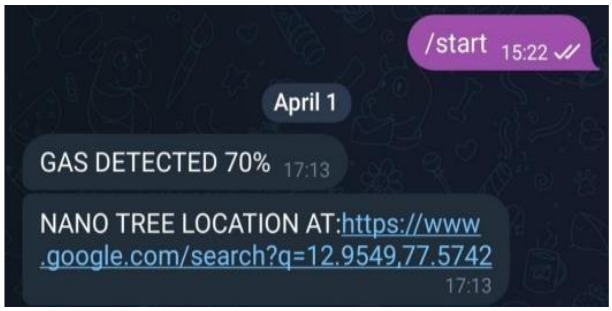

Fig 5: SMS showing the location of Nano Tree

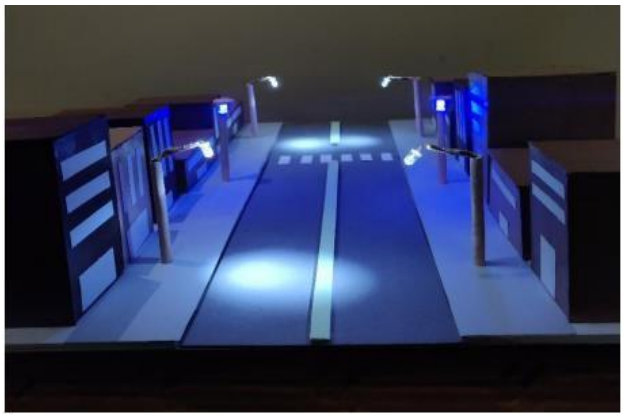

Fig 6: The prototype of Nano Tree in Urban areas for street light automation

Fig 7: Proposed Nano Tree is used for street lighting

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IV. CONCLUSION

The Arduino micro-controller-based Nano Tree and tracking system using an in-built GPS technique with NodeMCU attached is a significant contribution to the field of energy harvesting and pollution control systems. It provides a cost-effective, efficient, and user-friendly solution for controlling pollution levels and generating energy from renewable sources. The proposed system has the potential to revolutionize carbon trapping mechanisms and street light automation in various sectors such as urban infrastructure, charging stations, industries, and smart street lighting. The addition of features like IoT implementation can further enhance the performance and reliability of the system. The development of Nano Tree serves with a dual benefit of energy generation and pollution control, playing a significant role in creating a clean and sustainable environment. The proposed system also reduces the reliance on traditional fossil fuels for power generation, thereby reducing pollution levels to a great extent. Overall, using IoT technology in the development of Nano trees is a sustainable way to meet energy needs while minimizing environmental impact.

V. FUTURE SCOPE

The Nano Tree project uses the IoT (Internet of Things) technology to improve the efficiency and effectiveness of energy harvesting techniques and pollution control systems. As technology continues to advance, several potential future works can be explored to enhance this project. The future scope of this project includes fault detection, coin-based charging, and air purifiers.

The proposed Nano Tree project aims to harness the power from solar panels that are used in street light automation. In the realm of fault detection, pinpointing issues within street lights can be achieved through the utilization of dedicated sensors alongside microcontrollers or microprocessors. This approach not only enhances safety but also curtails maintenance expenses.

Currently, the project provides charging points to power up electronic devices from the excess energy that is derived from the solar panels and stored in batteries. An economic opportunity arises with the implementation of coin-based charging systems. Analogous to a vending machine, users would insert a coin which would then be validated and authorized, granting access to charge electronic devices or electric vehicles. The system could be integrated with photocatalytic materials for air purification that releases oxygen to the surroundings creating a cleaner and sustainable environment

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