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(RESEARCH ARTICLE)

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Solar powered solid waste management system using IoT

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Abstract

The amount of waste has been increasing dueto the increase in human population and urbanization. In cities, the overflowed bin creates an unhygienic environment. Thus degrades the environment, to overcome this situation, "Solar Powered Solid Waste Management System Using IoT" is developed. The system is powered by solar energy and separates the waste into three categories namely wet, dry and metallic.Each of the wastes are detected by the respective sensorsand gets segregated to respective bins. IoT is used to continuous monitor the dustbin in order to check whether the dustbin is full or not. The present work updates the real time data using IoT and the same can be conveyed to concerned administrators and can fetch the information using Android Application.

Keywords: Solid Waste Management; IoT; Solar Energy; Waste Segregation

1. Introduction

According to a report by The Energy and Resource Institute (TERI), India's annual waste generated was found to be 62 million tones. In India, 77% of waste isdisposed of in open dumps, 18% is composted and just 5% is recycled. A significant 34% of all waste is generated by just 16% per cent of the world's population, largely from high- income countries, but more than one-third of this waste is recovered throughrecycling and composting.

The garbage is collected from the streets, houses and other establishments on circadian basis, which is not an effective management system. Cleaning of garbage bin is not done when it is needed. Rest of the wastes are left scattered in the streets due to poor maintenance of garbage bins. The traditional way of manually monitoring the garbage bins is a complex, clumsy process and utilizes more human effort, time and cost. The existing system has no proper planning regarding the collection of garbage which makes the city or town. Unhygienic. As urban areas expand, the volume of waste generated has surged, necessitating innovative approaches to waste management. Solar panels and rechargeable batteries ensure a sustainable and eco- friendly power source for IoT enabled waste management infrastructure. Leveraging the power of IoT the system employs smart bins equipped with sensors to monitor fill levels in real-time. Algorithms analyze the data to predict fill levels, optimizing waste collection schedules and minimizing operational costs. The real time data can be conveyed to concerned administrators and can fetch the information using Android Application. unhygienic. As urban areas expand, the volume of waste generated has surged, necessitating innovative approaches to waste management. Solar panels and rechargeable batteries ensure a sustainable and eco- friendly power source for IoT enabled waste management infrastructure. Leveraging the power of IoT the system employs smart bins equipped with sensors to monitor fill levels in real-time. Algorithms analyze the data to predict fill levels, optimizing waste collection schedules and minimizing operational costs. The real time data can be conveyed to concerned administrators and can fetch the information using Android Application.

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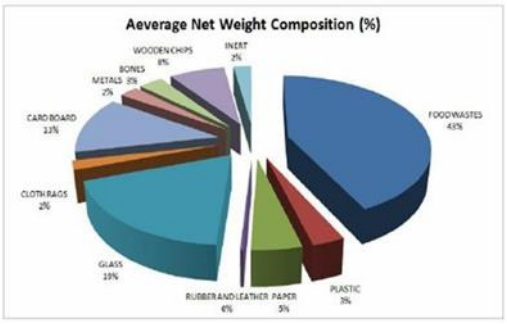

Figure 1 Average (% by weight) composition of MSW in India

1.1. Problem statement

The abundant increase in population lead to the improper waste disposal. Managing the garbage consumes more time and requires a lot of man power. The economic value of the waste generated is not realized unless it is recycled completely. The recyclingof solid waste is done by the rag pickers while doing the rag pickers get affected with many health problemssuch as skin infections, respiratory problems.

1.2. Objectives

- A successful design, construction and operation of a smart waste segregation and monitoring system using IoT will be proposed for a hygienic environment in the view of SMART CITY.
- To develop a system to utilize solar power for IoT sensors and other components reduces reliance on conventional energy sources.
- To Design a system to segregate the waste in to three main categories namely metallic, wet and dry.
- The Developed system updates the real time data using IoT and the same can be conveyed to concerned administrators and can fetch the information using Android Application.

1.3. Existing system

Existing system does not regularly update the level ofthe garbage bin to the authority. It intimates the municipality only through SMS alert. In some systemsRFID tag and reader is used so whenever the garbage truck comes near the bin it updates the current status ofthe bin to the worker in the truck. The worker then cleans the bin when it is filled. The labours who are cleaning the dustbins are also not taking any responsibility which makes the system worse in urgent cases. Proper monitoring of wastes is obligatory to runthe city clean and green. The conservative and manualgarbage monitoring and collection system is only available. The labors cannot always monitor the elevation and scent of the dustbin manually around allplaces of the city. No internet technology oriented systems which are more systematic, cost-effective andenergy efficient exist.

1.4. Proposed system

The proposed system uses solar energy for the operation. The foremost goal of this project is toautomatically segregate the wastes. An automatic trashsegregator segregates different types of waste with thehelp of ESP32 MCU and sensors. IoT based system created to monitor the trash segregation process The GSM module is used to send the real time data of binsto concerned authority.

2. Literature survey

[1].“Solar Powered IoT based Smart Solid WasteManagement System” M. Nirmala; K. Malarvizhi 18 January 2022, Publisher: IEEEIn this paper, The Experimental setup is designed in such a way that it automatically senses the distance of the waste in the receptacle using ultrasonic sensor andspeed of the heating process is adjusted by changing the switching frequency of the MOSFET switch. Also,it can be monitored in an Android application using IOT and the data can be viewed with the help of Wi- Fi from anywhere in the world.

[2].“Smart Waste Management and Garbage Monitoring Using IoT”-1.Mrs Sarmila SS ,2.Siva Kumar V,3.asanth Kumaur P K This paper briefsabout. The ultrasonic sensor used fullness of the smartbin. A Gas sensor node is installed in every Smart bin.The Gas sensor will detect hazardous gases on the dustbin due to some chemical waste and bio-waste. The Gas sensor will detect hazardous gases on the dustbin due to some chemical waste and bio-waste. The Ethernet shield

will be used to update the status ofthe bin whether it is have hazardous gas or not. The buzzer which gives alert when there is any hazardous gas from the smart bin. Smartbin providers are able toidentify and decide whether a particular area needs extra litter bins to be placed nearby or removal and relocate existing litter bins to other places where they areneeded.

[3].“Sensor Based Smart Dustbin for WasteSegregation and Status Alert” Kesthara .V1, Nissar Khan2, Praveen .S.P2, Mahesha .C2, Murali .N2: Thispaper briefs about “Automatic Waste Segregator” which sorts wastes into three different categories, namely metal, dry and the wet waste. Waste segregation means division of waste into dry waste and wet waste. The Trash management system is a stepforward to make the manual collection and detection of wastes automated in nature. Using embedded technology to continue monitoring the dustbin in orderto check whether dustbin is full or not. The sensors senses the amount of waste in the containers if it reached the maximum container capacity, sends instant messages to the trash management departmentwhich deploy them to collect the garbage in no time.

[4]. Smart Waste Segregation and Monitoring Systemusing IoT-V.Sowndharya1*,P.Savitha1, S.Hebziba Jeba Rani 2- Theforemost goal of this paperis to automatically segregate the wastes and to perceive thelevel of the dustbins which is delivered through wireless mesh network. With such information litter bin providers and cleaning contractors are able tomake better decision for the efficient disposal. IRsensor identifies the objects, Moisture and metal sensors detects the wet and metal waste. Ultrasonic sensor observes the levels of bin. The waste is droppedinside the bin where the sensor identifies the type of the waste. The Bin consists of three partitions inside were each bin collects each waste respectively.

2.1. System requirements

2.1.1. Hardware requirements

Solar panel

Solar panel 5W 12 volt, is composed by 36 cells, the crystal that has been used for the construction of this solar panel is very low in lead content, allowing a large transmissivity of the solar radiation, allowing cells to capture the most energy from the sun as possible.

Figure 2 Solar Panel

Battery

The rechargeable battery is used. It is charged by the solar energy. Supplies voltage to the whole system. The battery is of 6v and 4.5AH.

Figure 3 Battery

ESP32 MCU

A feature-rich MCU with integrated Wi-Fi and Bluetooth connectivity for a wide-range of application. ESP32 is a series of low-cost, low-powersystem on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The power amplifier, low- noise receive amplifier, filters, and power- management modules. ESP32 is created anddeveloped by Espressif Systems, a Shanghai- based Chinese company, and is manufactured by TSMCusing their 40 nm process. It is a successor to the ESP8266 microcontroller.

Figure 4 ESP32 MCU

Servomotor

A servomotor is a rotary actuator or linear actuator thatallows for precise control of angular or linear position,velocity and acceleration. It consists of a suitablemotor coupled to a sensor for position feedback. It alsorequires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. SG90 is the most popular 9g servo in the world, SG90 digital servo is the new version of SG90 analog servo. Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like thestandard kinds but smaller. It can use any servo code, hardware or library to control these servos.

Figure 5 Servomotor

Soil Moisture Sensor

The soil moisture sensor is one kind of sensor used togauge the volumetric content of water within the soil.These sensors measure the volumetric water content not directly with the help of some other rules of soil like dielectric constant, electrical resistance, otherwiseinteraction with neutrons, and replacement of the moisture content. The moisture sensor consists of twoprobes that are used to detect the moisture of the soil.These two probes are used to pass the current throughthe soil and then the sensor reads the resistance to getthe moisture values.

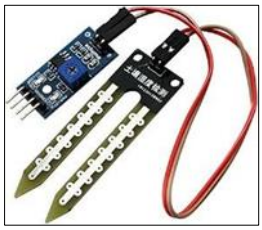

Figure 6 Soil Moisture Senso

Metal Sensor

A metal sensor is an electronic instrument which detects the presence of metal nearby. Orange 8mm NPN Inductive Proximity Sensor RM18 DC6~36V (Unshielded) is a brand new inductive proximity sensor that detects a metal object.

The M18 indicatesa cylinder type whose diameter is 18mm. The operating voltage range is VDC 6~36V, but the nominal voltage is 30V with detecting distance of 8mm. The sensor has 3 wire and NO (Normally open)type output with RED LED indicator

Figure 7 Metal Sensor

IR Sensor

Infra-Red sensor (IR sensor) is an electronic device that measures infrared (IR) light radiating from objectsin its field of view. Operating voltage is 5V and the current consumption is 1A. The detection range is 2cm-30cm.

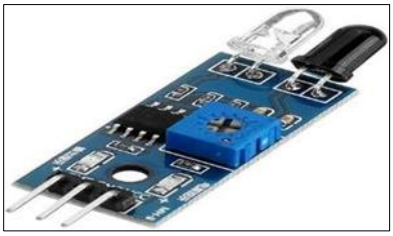

Figure 8 IR Sensor

Relay

A relay is an electrically operated switch. It consists ofa set of input terminals for a single or multiple controlsignals. Relay works on the principle of electromagnetic induction. With a relay, users do notneed to manually turn the switch to isolate or change the state of an electric circuit. Input voltage is 5V

Figure 9 Relay

DC Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy.Most electric motors operate through field and winding currents to generate force powered by direct current (DC) sources, such by alternating current (AC)sources such as power grid, inverters or electricalgenerators.

Figure 10 DC Motor

Ultrasonic Sensor

Ultrasonic sensors are based on measuring theproperties of sound waves with frequency above the human audible range. They are based on three physicalprinciples: time of flight, the Doppler effect , and the attenuation of sound waves. The HC-SR04 Ultrasonic(US) sensor is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. The module has two eyes that projects in the front which forms the Ultrasonic transmitter and Receiver.

Figure 11 Ultrasonic Sensor

2.1.2. Software requirements

Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application. It is used to write and upload programs to ESP32 board. Compatible with other vendor development boards.

Figure 12 Arduino IDE

2.1.3. Blynk IoT

Blynk is an IoT platform for ios or Androidsmartphones that is used to control Arduino, RaspberryPi and Node MCU via the Internet. This application isused to create a graphical interface or human machineinterface by compiling and providing the appropriate address on the available widgets.

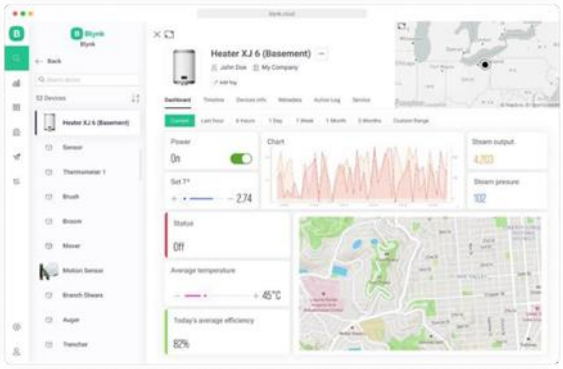

Figure 13 Blynk IoT

3. Methodology

This paper deals with Waste Segregation for Smart cities by using solar energy and IoT technology. To overcome the existing problem a well-organized wastesegregation and monitoring system has been designed.It is an IoT based Waste Segregation and monitoring system which is an innovative way to keep the cities clean and healthy. The foremost goal of this paper is to automatically segregate the wastes and to perceive the level of the dustbins which is updated through IoT.With such information, litter bin providers and cleaning contractors are able to make better decision for the efficient disposal.

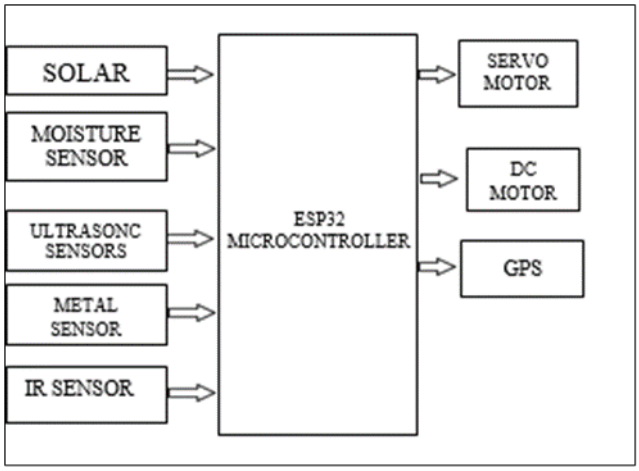

Figure 14 Block diagram

The solar panel converts solar energy into electrical energy. This electrical energy is to be stored in the battery which supplies the power to the system. The ESP32 Microcontroller is used. All the data from the sensors are given as input to the microcontroller and then it analyses the input data and takes necessary action according to the dumped code. Microcontrollertakes the input from the metal and moisture sensors and then analyse it and sends the output to the servo motors to dump the waste in the appropriate bin. Ultrasonic sensor which measures the level of the waste in the bin sends the data to the microcontroller and then it updates the data to the concerned authoritythrough Blynk IoT Android application.

3.1.1. FLOWCHART

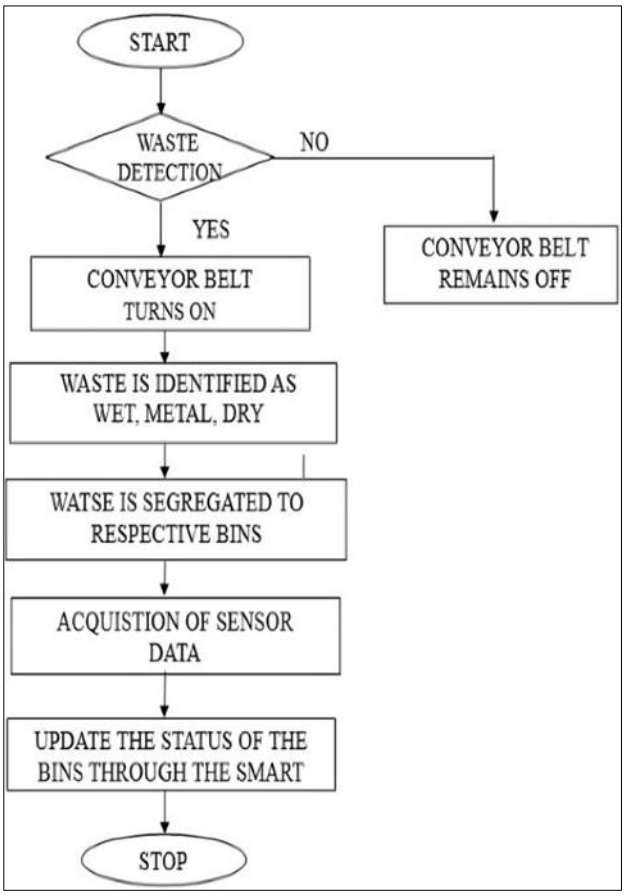

Figure 15 Flow Chart

The flowchart of the source code is given in Figure.13.When the code is initialized, the ESP32 microcontroller starts reading the values from the ultrasonic sensor and only if the waste is detected on the conveyor belt, the whole system is powered ON. The waste starts moving on the conveyor belt and the three types of waste (wet, dry, metal) are detected and segregated into their respective bins. Further the levelof the segregated waste in each dustbin is monitored and updated to the application.

3.1.2. Circuit diagram

Figure 14 shows the Circuit diagram of the project. The connection of components is explained below:

ESP32 Microcontroller is powered by 5V at pin 30. The voltage is regulated by L7805 and L7809 voltageregulators, the two ground pins (4, 27) are connected to ground. ESP32 is reset using the pins 3 and 28.Relay is connected to the pin 6 of the ESP32, and it is powered by 5V supply. Coil End 1 and coil End 2 are used to trigger (On/Off)the Relay, normally one end is connected to 5V and the other end to ground.

Echo and Trigger pins of four ultrasonic sensors are connected to the Echo and Trigger pins of ESP32 MCU. The Echo and Trigger pins (pin 2 and 3) of US0is connected to pin 9 and 12,US1 is connected to pin 10 and 13, US2 is connected to pin 11 and 14, US3 isconnected to pin 15 and 16 of ESP32 Microcontroller.Pin 4 and 1 of Ultrasonic Sensor are connected to Ground and 5V respectively.

Pin 2 of Moisture sensor is connected to 19 of ESP32.Pin 3 ad 1 of moisture sensor are connected to the ground and 5V supply respectively.

Pin 2 of metal sensor is connected to Pin 5 of ESP32, Pin 1 and 3 of metal are connected to ground and 5V of ESP32 respectively.

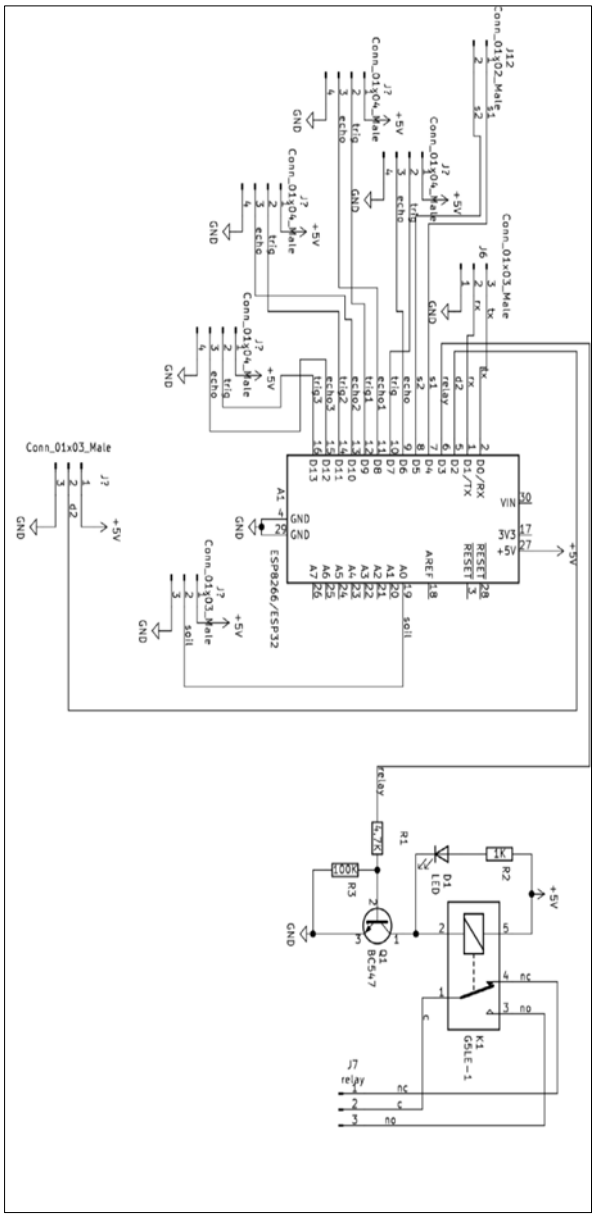

Figure 16 Circuit Diagram

Working

STEPS

The battery is charged by solar energy.

The waste is collectively dumped into a main dustbin.The waste is dropped on the conveyor belt where the Ultrasonic sensor identifies the waste. Only after the waste is detected on the conveyor belt the system is powered ON, thus conserving the energy.

The conveyor belt is operated by a DC motor.

After the System is turned ON, the waste starts movingthrough the conveyor belt.

A moisture sensor is placed which detects the wetwaste and dumps it into the bin placed below and thena metal sensor is placed which detects the metallicwaste and dumps it into the dustbin placed below andthe remaining kind of waste is considered as dry wasteand these waste is dumped into the bin placed below. This process is operated by a servomotor.

Ultrasonic sensors are placed at the top of the eachdustbin to observe the levels of bin.

The status of the bin is monitored and displayed at each level in the server which can be viewed by the concerned authority through an application and gets the bin location.

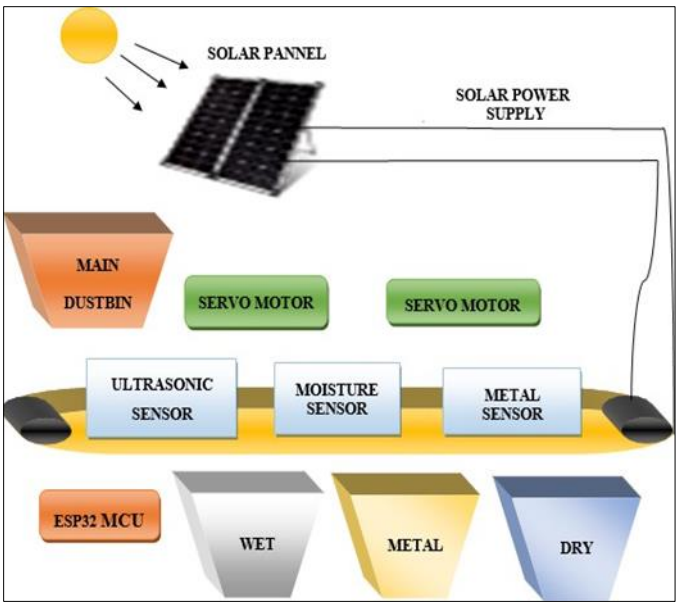

Figure 17 External View of Smart Waste ManagementSystem Using IoT

4. Results and discussion

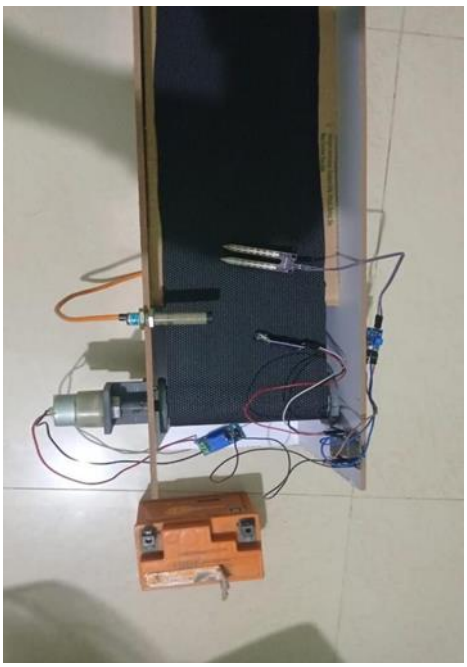

Figure 18 Top view of the setup

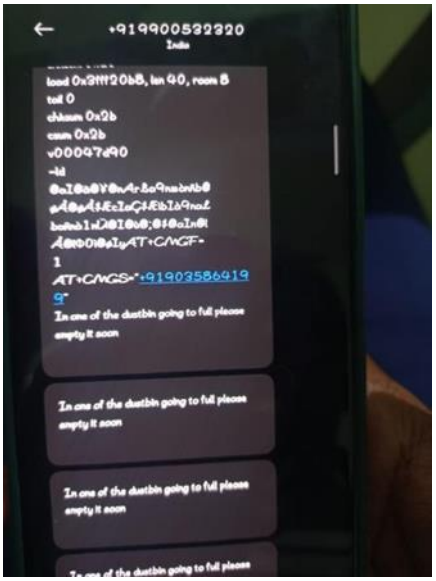

Figure 19 Sending message to the given Number

Figure 20 Data Fetching in Blynk

Figure 21 Measuring Segregated MetalWaste In The Bin

Figure 22 Measuring Segregated WetWaste In The Bin

Fig.16 Shows the final setup of the Smart waste management using IoT. It consists of a main dustbin which is located on the top of the conveyor belt whichis powered by two DC motors. The three dustbins areplaced below the conveyor belt to accumulate the segregated waste (wet, dry, metal). The Fig no. 19, 20 depicts the segregation of metal,dry and wet wastes in the respective bins and also thedata of the bin level is updated to the concernedauthority through messages as shown in Fig no. 17 and18.

4.1. Advantages and applications

4.1.1. Advantages

- Renewable Energy: Solar power reduces reliance on non-renewable energy sources, making the system environmentally sustainable.
- Cost Savings: Operating costs are minimized since solar energy is free once the system is installed, reducing electricity bills.
- Remote Monitoring: IoT allows for real-time monitoring of waste levels, temperature, and otherparameters, enabling timely interventions and efficient resource allocation.
- Data Analytics: IoT sensors collect data that can be analyzed to optimize waste collection routes, schedule maintenance, and improve overall efficiency.
- Environmental Impact: By efficiently managing waste, such a system reduces pollution, greenhouse gas emissions, and landfill usage, contributing to a cleaner environment.
- Scalability: Solar-powered IoT systems can be easily scaled up or down to accommodate different-sized communities or changing wastemanagement needs.

4.1.2. Applications

- Urban Areas: Implementing smart waste bins in cities can optimize waste collection routes, reduceoverflow, and improve overall cleanliness.
- Industrial Zones: IoT-enabled waste managementsystems help industries monitor and manage theirwaste output, ensuring compliance with environmental regulations.
- Healthcare Facilities: Hospitals and clinics can benefit from IoT-powered waste management systems to ensure safe disposal of medical waste and reduce the risk of contamination.
- Rural Communities: Remote monitoring of wastebins in rural areas helps manage waste efficiently,even in areas with limited access to traditional waste management services.

5. Conclusion

The solar-powered solid waste management system using IoT technology offers efficient and sustainable solutions for waste management challenges. Byharnessing renewable solar energy and IoT. capabilities for remote monitoring and data analysis, the project improves waste collection, reduces overflow, minimizes environmental impact, and enhances community engagement. It is suitable for various environments and sectors, providing cleaner, healthier, and more sustainable communities through smarter waste management practices.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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