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IoT-Based Smart Carbon Footprint & Energy Waste Detection System for MSMEs

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Abstract : *Micro, Medium Enterprises which are often called MSMEs use a lot of electrical energy every day. This can cause a lot of energy being wasted. Can also create more carbon emissions. Traditional energy monitoring systems only show how much power is being used. They do not help much in finding usage or understanding the effect on the environment. This paper introduces an IoT-Based Smart Carbon Footprint & Energy Waste Detection System for MSMEs. The system uses Industrial Internet of Things or IIoT, technology. The system has an ESP32 device along, with voltage and current sensors to keep track of how much energy machinesre using. The information gathered is sent over Wi-Fi to an IoT cloud platform. This platform allows for real-time checking and looking at the data. The system can find when energy use is not normal. It can also figure out the carbon footprint that comes with that.. It can give tips on how to save energy. This way MSMEs can keep track of how energy they use. They can reduce the amount they do not need. They can also cut down on carbon emissions. They can make their energy use more efficient. The system offers a cost, real-time and easy to expand way to help make industrial work more sustainable.*

Keywords: Micro, Medium Enterprises

I. INTRODUCTION

Micro, Medium Enterprises are a big part of the industrial sector. These industries use electricity for things like machines, lighting and cooling systems. They use it every day.. When they use electricity all the time and do not use their equipment properly they waste a lot of energy. This means they pay more for electricity. They also make the air dirtier. In a lot of industries they use old fashioned meters to see how much energy they use but these meters do not show where the energy is being wasted.

Now we have something called the Industrial Internet of Things that makes it easier to keep an eye on what's happening in industries. We can use sensors to get information from machines and a small computer can look at the information and send it to a website. In this project we use something called an ESP32 with sensors to measure how much energy the industrial equipment uses. We can look at the information we collect on a website.

The Smart Carbon Footprint and Energy Waste Detection System, for Micro, Medium Enterprises is a system that watches how much energy is used and finds out if any energy is being wasted. The system also tries to figure out how bad stuff is put into the air when energy is used. If the system finds out that energy is being wasted it can send a warning. Give ideas on how to use less energy.

The main goal of this project is to help Micro, Medium Enterprises understand how they use energy and find simple ways to stop wasting it. The system we propose is cheap and practical. It can help small and medium industries use less energy make less pollution and be more efficient.

II. RELATED WORK

Many researchers have worked on monitoring energy consumption using IoT technology. In these systems sensors are connected to machines to collect information like voltage, current and power usage. The data is then sent to a

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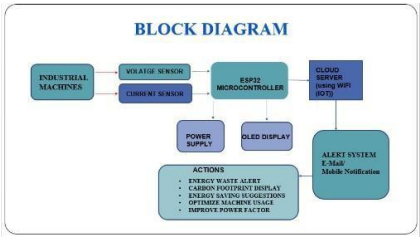
monitoring platform, where the user can check the energy consumption without being physically close to the machine. Some recent studies have used IIoT for energy monitoring. These systems help in collecting energy data all the time and make it easier to spot changes in power consumption. This type of monitoring is useful for industries because even a small amount of energy wasted over a time can raise the overall electricity cost.

Researchers have also looked at energy prediction and unusual consumption detection. By comparing energy usage with past data strange changes in machine consumption can be spotted. This can help in finding machines that might be working inefficiently or using power than they should. Another important area is carbon emission monitoring. Since electricity usage is linked to carbon emissions energy data can be used to calculate the amount of carbon produced during operations. However many existing works focus on energy monitoring or carbon emission calculation. From these studies it can be seen that there is a need for a system that combines energy monitoring, waste detection and carbon-footprint estimation. Our proposed system focuses on this idea using ESP32, voltage and current sensors and IIoT-based cloud monitoring with the aim of making the solution easy to use and affordable, for MSMEs.

III. SYSTEM ARCHITECTURE

A. Hardware Components

The proposed system is built using a few basic hardware components to measure and monitor the energy used by industrial equipment. The main components used in the system are,



• ESP32 Development Board: The main part of this circuit is an ESP32 development board. It first reads signals from voltage sensors and current sensors, then calculates consumed power and total energy in the machine. It then uploads them to an IoT cloud platform using Wi-Fi.

• ACS712 Current Sensor: This sensor measures the current taken by the connected machine. The measured current value is given to the ESP32 for calculating power consumption.

• ZMPT101B Voltage Sensor: The ZMPT101B is used to measure the AC voltage supplied to the machine. The voltage reading is also sent to the ESP32.

• Jumper Wires: Jumper wires are used to connect the Arduino UNO to the servo motor and other parts of the system. They make it easy to get all the parts working together and talking to each other.

. Breadboard: The breadboard is really useful because it helps us set up circuit connections in a way. This makes it easy to connect components and make changes without having to solder anything. The breadboard is great for working with circuits.

.Buzzer and LED: The buzzer and LED are used to give a warning when the system notices excessive or unusual energy consumption.

• OLED Display: The OLED display shows the measured values directly. It can display voltage, current, power, and energy consumption.

• Power Supply: A suitable power supply is used to provide power to the ESP32 and the other electronic components.

.IoT Cloud Platform: The measured values are sent from the ESP32 to the cloud through Wi-Fi, where the user can view the machine's energy consumption.

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B. Software Architecture

The ESP32 is programmed to read the voltage and current values from the connected sensors. From these readings, the power used by the machine is obtained and the energy consumption is recorded. After measuring the sensor readings, the ESP32 sends the readings through Wi-Fi to the IoT dashboard. The machine readings can then be checked online. A limit is also set for power consumption; when the reading goes above this value, the system gives a warning. The same energy data is used to work out the carbon emission and to point out cases where more power is being used than expected.

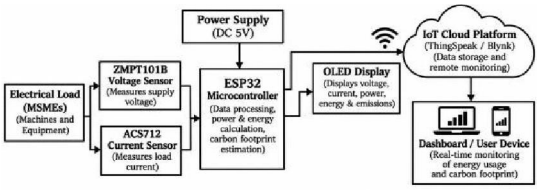
IV. CORE CONCEPT AND DESIGN PRINCIPLES

Our system is mainly made to find out where electricity is being used and where it may be getting wasted in an MSME. The voltage and current sensors take the readings from the machine and pass them to the ESP32. The sensor values are used to calculate the power consumed by the connected machine and to keep track of the energy used. The readings are then made available on the IoT dashboard through the ESP32 Wi-Fi connection. This allows the machine's power usage to be checked without going to the monitoring unit. The energy reading is also used to estimate the amount of carbon emission related to the electricity used. If the machine starts taking more power than the normal value, the system gives an indication so that the user can check the machine.

The setup uses ESP32, voltage and current sensors, and an OLED display, keeping the number of components low. ESP32 handles the sensor readings as well as the Wi-Fi connection, while the OLED display shows the values near the machine. The same arrangement can also be extended to other machines by adding the required sensing section. This makes the system suitable for monitoring energy consumption in small and medium-scale industries.

V. OPERATIONAL WORKFLOW

- Connect the Load – The machine to be monitored is connected to the voltage and current sensing section.
- Take Voltage Reading – ZMPT101B measures the voltage supplied to the machine.
- Take Current Reading – ACS712 measures the current taken by the machine.
- Read the Values – ESP32 receives both sensor readings.
- Calculate Power – The ESP32 uses the voltage and current values to find the power consumed.
- Show the Reading – The OLED displays the voltage, current, power, and energy values.
- Send the Data – ESP32 uses Wi-Fi to put the readings on the IoT cloud platform.
- Check Energy Usage – The stored readings are checked to find any unusual increase in power consumption.
- Find Carbon Emission – The energy consumed is used to work out the related carbon footprint.
- Give Warning – When the power crosses the selected limit, the LED and buzzer indicate the condition so the machine can be checked.



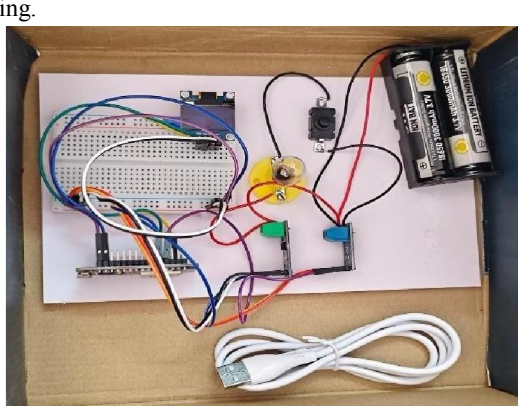
VI. IMPLEMENTATION AND RESULTS

A. Prototype Development

The functional prototype using an ESP32, ACS712 current sensor, ZMPT101B voltage sensor, OLED display, LED, and buzzer. The voltage and current sensors were placed on the machine side to take the required readings. These readings are given to the ESP32, where the power and energy values are calculated. The OLED screen shows the

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readings near the setup. The ESP32 uses its Wi-Fi connection to send the sensor values to the IoT platform, where the readings are stored for later checking.



B. System Performance

The setup was checked by changing the load connected to the system. Different load conditions were tested, and the OLED showed the corresponding power readings. The ESP32 uploaded these readings to the IoT platform through Wi-Fi. We also checked the warning function by setting a limit for power consumption. Once the reading went above the limit, the LED and buzzer turned on. From these tests, the prototype was able to measure the machine's energy usage, show the readings, upload the data, and indicate higher power consumption.

VII. DISCUSSION

The readings obtained from the machine help us understand how much electricity it is using during operation. When the machine load is increased, the power reading also goes up. This makes it easier to notice a sudden rise in power usage. The OLED gives the readings at the machine, while the IoT platform keeps the values for checking later. The warning circuit is useful when the power goes above the chosen limit, as the LED and buzzer immediately indicate the change.

The energy values can also be used to work out the carbon footprint of the machine. By looking at the readings over time, the user can find machines that are using more electricity than expected. This can help in taking simple steps such as checking the machine condition, avoiding unnecessary operation, or reducing idle running time. Overall, the setup gives MSMEs a practical way to keep track of electricity usage and reduce avoidable energy consumption.

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VIII. CONCLUSION

The proposed project was developed to monitor electricity usage in MSMEs and to find unnecessary energy consumption in industrial machines. The system uses an ESP32 as the main controller for collecting and handling the sensor readings. The ACS712 sensor is used to measure the current taken by the connected machine, while the ZMPT101B sensor measures the supply voltage. The ESP32 uses the sensor readings to find the machine's power and energy usage. The OLED screen shows these values while the machine is working, so they can be checked at the setup itself. The ESP32 also uses Wi-Fi to send the measured values to the IoT platform for storing and checking the data. This helps the user keep a record of the machine's energy usage over time.

A fixed power limit is used to notice higher-than-normal consumption. When the measured value crosses this limit, the LED and buzzer provide a warning. This allows the user to check the machine and find the reason for the increased power usage. The energy values collected from the machine are also used to estimate its carbon footprint. By looking at the energy readings, industries can understand which machines consume more electricity. This information can be useful for reducing unnecessary machine operation and avoiding energy wastage.

The system does not require complicated equipment and can be built using commonly available components. The use of ESP32 also makes the IoT connection easier because Wi-Fi is already available on the board. The setup can be

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extended later by adding more sensing units for monitoring additional machines. It can also be improved with a better dashboard and longer-term energy records. The proposed system therefore gives MSMEs a practical way to monitor their machine energy usage and keep track of carbon emissions. Overall, the project combines ESP32, energy sensors, IoT monitoring, energy-waste indication, carbon-footprint estimation in one system.

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