Monitoring Energy Consumption using Arduino

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Abstract

This abstract outlines a comprehensive approach for measuring and monitoring energy consumption using an Arduino-based system, integrated with cloud computing and web application technologies. With rising interest in energy optimization, this project aims to provide precise, accessible, and real-time energy data.

The system employs an Arduino microcontroller, paired with a YHDC Current Transformer SCT-013-000 sensor, to measure current. Using analog-to-digital conversion, the Arduino calculates energy consumption by converting power (in watts) to energy (in watt-seconds) and subsequently to kilowatt-hours (kWh). The processed data is transmitted every 10 seconds to a cloud-based PostgreSQL database, facilitated by a Python script connected to the Arduino's serial monitor.

A Flask-based web application, supported by the Dash framework, visualizes the collected data. This app allows users to filter data by month and day, enabling detailed analysis of consumption patterns. Additionally, data syncing is configured to run periodically in the background to ensure the database remains up-to-date with the latest measurements. The integration of a cloud database enhances accessibility, allowing users to track energy usage remotely and make data-driven decisions for energy optimization.

By utilizing the Arduino's compatibility with various sensors and a robust cloud infrastructure, this system presents an efficient and scalable solution for real-time energy monitoring.

I. Introduction

This project aims to develop and deploy an Energy Monitor system, designed to provide real-time energy consumption data for a residential setting. The core component of the system is an Arduino-based microcontroller, responsible for collecting and processing energy consumption data from various sensors. This data is then transmitted to a web server, allowing for remote monitoring and analysis.

The web application, built using Python and Flask, provides a user-friendly interface to visualize energy consumption patterns, identify potential areas for energy savings, and generate insightful reports. This project leverages the power of open-source technologies to create a cost-effective and customizable solution for energy monitoring.

Key Features:

- Real-time monitoring: The system provides up-to-date energy consumption data.
- Remote access: Users can access and analyze data from anywhere with an internet connection.
- Data visualization: The web application offers various visualization tools for easy data interpretation.
- Energy efficiency insights: The system helps identify areas for energy savings and optimization.

This document will detail the system's architecture, hardware implementation, software development, and deployment process. It will also include a comprehensive evaluation of the system's performance and potential future enhancements.

II. Materials

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i. Arduino Micro-controller

- Microcontroller: The heart of the project. It processes the data received from sensors, performs calculations, and controls other components.
- Digital and Analog Pins: These pins are used to connect sensors and actuators. Digital pins provide high or low signals, while analog pins can read varying voltage levels.
- Power Supply: The board can be powered by a USB cable or an external power supply.
- Serial Communication: The board can communicate with a computer or other devices using a serial connection.

ii. YHDC Current Transformer SCT-013-000

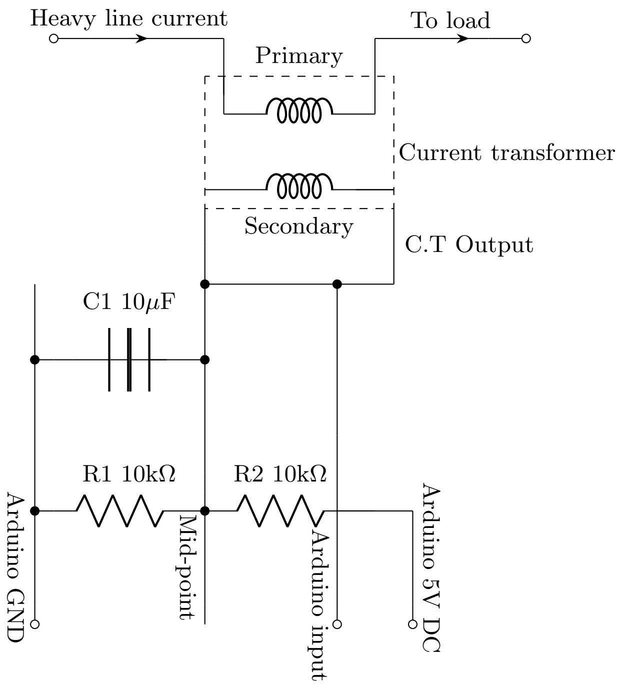

Figure 1: Current transformer circuit with Arduino

- Non-invasive Measurement: It measures the current flowing through a wire without physically breaking the circuit.

- Magnetic Induction: It works based on the principle of electromagnetic induction.

- Output Signal: It produces a small AC voltage proportional to the current flowing through the wire.

- Safety: It allows for safe measurement of high currents without the risk of electric shock.

iii. Liquid Crystal Display

- Display: It displays information like voltage, current, power consumption, and other relevant data.

- Backlight: It provides illumination for better visibility.

- Interface: It connects to the Arduino board through digital pins to receive and display data.

- Types: There are various types of LCDs, including character LCDs and graphic LCDs. [1]

iv. Other Potential Components:

- Voltage Sensor: Measures the voltage entering the circuit.

- Temperature Sensor: Monitors the temperature of the system or environment.

- Power Supply: Provides the necessary power for the Arduino and other components.

- Resistors: Used to limit current and divide voltage.

- Capacitors: Used to filter noise and store energy.

III. System Design

The energy monitoring system consists of three main components: the Arduino microcontroller, the YHDC Current Transformer (CT) SCT-013-000 sensor, and a cloud-based PostgreSQL database accessible through a web application. Each component plays a vital role in capturing, processing, storing, and displaying energy consumption data in real-time.

i. Hardware Components

The system's hardware includes:

- **Arduino Microcontroller:** The Arduino serves as the primary data collection unit, converting analog signals from sensors to digital data for processing. It calculates the instantaneous power and energy usage based on current measurements from the CT sensor.

- **YHDC SCT-013-000 Current Transformer Sensor:** This non-invasive sensor measures the AC current flowing through a wire. It generates an analog signal proportional to the current, which is read by the Arduino's analog input.

- **AC-to-AC Power Adapter:** To measure AC voltage, an AC-to-AC adapter is used. This adapter steps down the AC voltage to a safe level compatible with the Arduino's analog input, allowing it to monitor real-world voltage values accurately.

ii. Software Components

The software components of the system include:

- **Data Processing on Arduino:** The Arduino processes signals from the CT sensor and calculates power by combining current and voltage values. The calculated energy data is sent to a local SQLite database, which is later synced with a cloud database.

- **Python Data Transfer Script:** A Python script interfaces with the Arduino's serial monitor and transfers the processed data to a cloud-based PostgreSQL database at intervals of 10 seconds.

- **Flask Web Application:** A Flask-based application with Dash visualizes the data, allowing users to filter by month and day to observe consumption trends. This user interface provides an accessible and flexible way to monitor energy usage over time.

iii. Data Flow and Operation

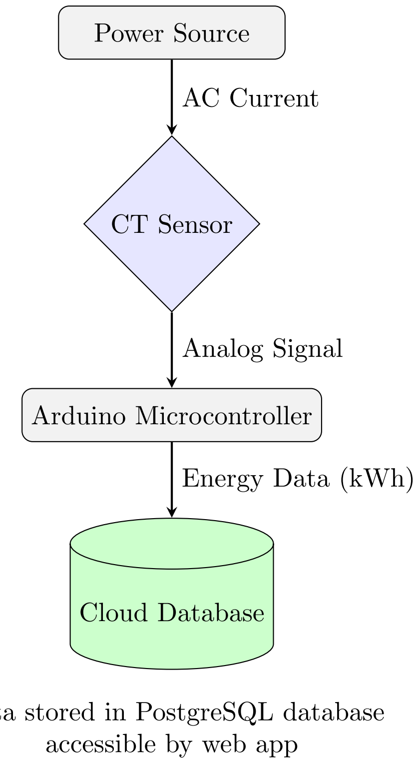

Figure 2: Process Flow Diagram of the Energy Monitoring System

The system operates as follows:

1. The Arduino reads analog signals from the CT sensor and the AC-to-AC adapter.
2. It processes these signals, calculates energy consumption in watt-seconds (later converted to kWh), and sends the data to the Python script.
3. The Python script logs the data in a local SQLite database, which then syncs to a PostgreSQL cloud database every 10 seconds.
4. The web app fetches the latest data from the cloud database, displaying it with interactive filters for user analysis.

This modular design, combining hardware and software elements, enables real-time, remote monitoring of energy usage.

IV. Measuring AC Voltage with an AC to AC power adapter

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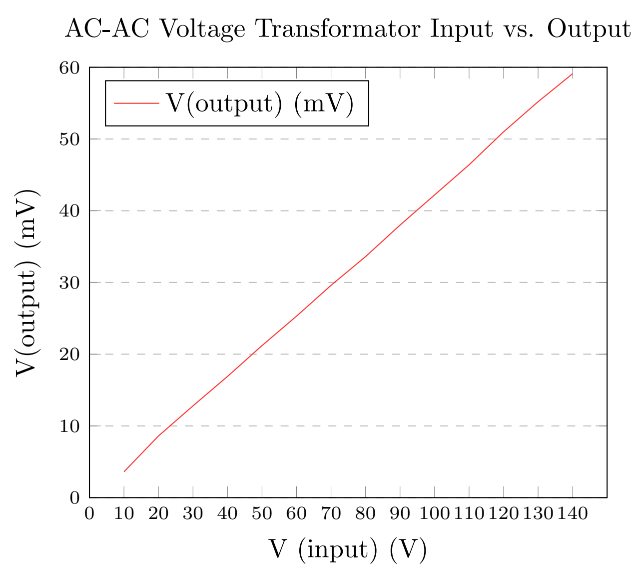
Table 1: AC-AC Voltage Transformator Data

V (input) (V)	**I (mA)**	**V(output) (mV)**
10	0.59	3.6
20	1.15	8.6
30	1.7	12.8
40	2.25	16.9
50	2.8	21.2
60	3.4	25.3
70	3.96	29.6
80	4.52	33.6
90	5	38
100	5.67	42.2
110	6.21	46.4
120	6.77	51
130	7.38	55.2
140	7.9	59.1



References

[1] OpenEnergyMonitor. Learn: Electricity moniroting. `https://docs.openenergymonitor.org/electricity-monitoring/index.html#learn-electricity-monitoring`. Accessed: 2024-04-30.