ECE445 Senior Design RFA

Project Name: Submetering of ECEB

Team Members: Xiaoyi Shen(xiaoyis2), Xiaolin Wu(xw5), Tingyu Wang(tingyuw2)

Problem

Although our ECE building has the measurement of the total power generated by the solar panels on the roof and has its measure of total power consumption, it still lacks the ability to track the power consumed by each and every classroom, lab, and office.

Solution Overview

Our solution for sub-metering the building is to build local metering system using 3-phase power meters that are placed inside rooms as well as a remote data communication system. The localing meter readings will be collected by a Raspberry Pi Zero in each classroom, which run on MQTT network protocol and are programmed to guarantee the error tolerance of the system in any possible conditions (Internet failure, local power failure, server down, .etc), and then send the information as desired to a centralized server for front-end requirement such as displaying and long-term data storing.

Solution Components

Sensor and local metering subsystem

The overall design is shown in Figure(1) below. The design is broken into three parts.

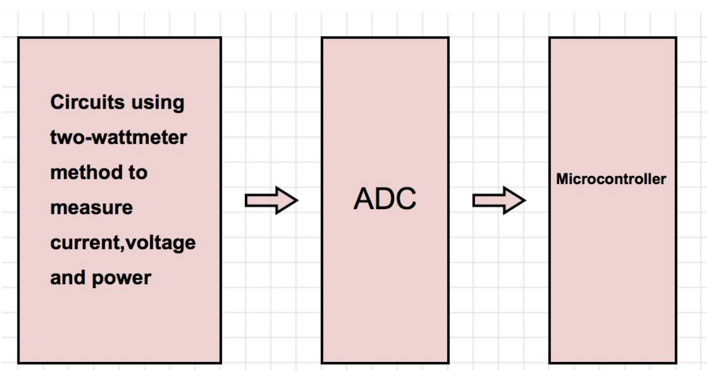

Figure 1

The first part consists of design the circuit measuring the phase current, phase voltage and the total power. The second part will be the ADC of the sensed signal. The ADC converts the analog signal to digital signal for the third part, the microcontroller, to calculate, update and store the power consumption over a specific time period.

To directly measure the current from the source in the classroom, we plan to set up a 3-phase two-wattmeter circuit with four hall-effect sensors and two shunt resistors for measuring the total current flow into the target rooms.

The connections for Star/Delta connected loads for measuring power by two-wattmeter method is shown in Figure(2) below. We plan to use two hall-effect sensors to measure two phase currents. The other two hall-effect sensors and two shunt resistors are inserted between Phase R and Phase Y and between Phase R and Phase B. The product of the current and resistance represents as the phase voltage. Then we can get two phase currents and two phase voltages and the total power measured by two wattmeter can be obtained by adding products of the phase current and phase voltage.

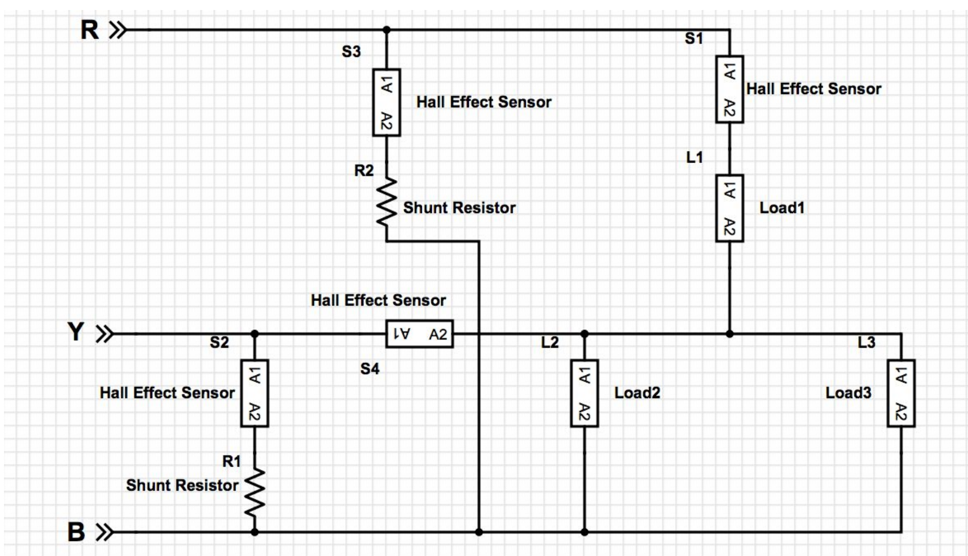

Figure 2

Current Control Subsystem

To deal with the high current involved in our measurement (approximately 200A ~ 400A), we propose to make a current transformer to reduce the high amp current using a small magnetic coil curled by copper wires as shown below in figure 3. We have seen similar products based on our research online and thus we believe such device system can be integrated into a very small component on our PCB board as shown in Figure 4. We propose this method to make 400/40 conversion on the current amps to collaborate with our measurement devices.

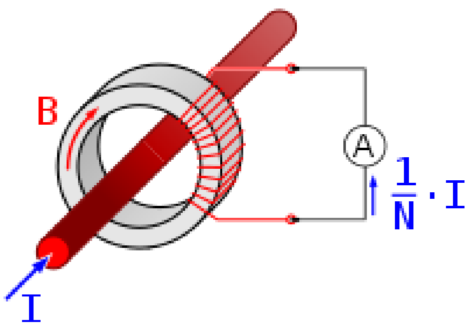

Figure 3

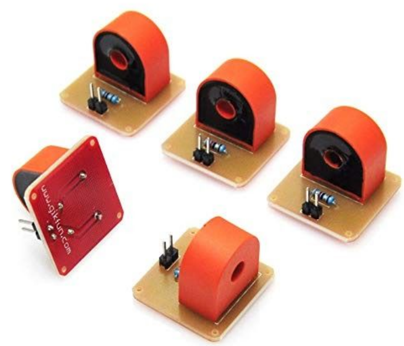

Figure 4

Communication System

The communication system is built up by servery local devices in each class room and a server device. The interconnection between devices will be built in an IoT manner to ensure the reliability and efficiency.

Local Devices

The local devices will be made up by connecting a Raspberry Pi Zero to the metering sensor. Raspberry Pi is a single-board computer that run unix based operating system on it. And Raspberry Pi Zero is a lightweight version that cost only $10 with minimum sacrifice of the performance. The reason we choose Raspberry Pi Zero instead of a microcontroller is that Raspberry Pi is more established for high-end functionalities is that:

1. It support external usb devices for local storage or other devices, this provides us with great scalability and we could easily expand the system in future if needed.
2. It could run Python language directly. We will write the code in Python because for shorter employment time and python library gives us more flexibility than C. Most microcontroller needs to compromise to Cython which has some hidden bugs.
3. Raspberry Pi is more established for internet connection. Some microcontroller suffers from bad connection due to excessive power drain or heating issues with WiFi module while Raspberry Pi is more reliable with WiFi.

4. Raspberry Pi ‘s general purpose I/O pins provides 14M Hz reading speed according to wiringPi speed test which is sufficient for our requirement of 10 Hz reading.
5. The most important feature that Raspberry Pi provided is that it could be accessed with SSH so we could debug remotely through internet without pulling the chip out and reflash the codes.

We will connect the Pi and the powermeter through I2C interface. Pi used microSD card as hardware, we could use a 32 GB sd card to support both the operation system and the requirement to store local readings for 96 hours.

Pi Zero use Network time if connected to the Internet. We need an external peripherals called real time clock (RTC) for Internet lost conditions. We will need to send timestamp to the server side for processing.

MQTT Protocol

MQTT protocol is a lightweight publish/subscribe network protocol commonly used in IoT devices communication. The reason we choose it because:

1. It is support on a wide range of network protocol that are ordered, lossless and bi-directional. This includes but is not limited to TCP/IP. We could connect on IllinoisNet to implement this protocol.
2. It is very easy to implement. It has shared description and topic aliasing. We basically needs only three functions for all devices with only alternating the topic name. It was significantly more efficient than writing socket in Python.
3. It is available in python. We just need to install and import paho-mqtt packages to use it.

Server Devices

Many devices could support MQTT. From the budget perspective we will use Raspberry Pi 3. It has improved RAM size compared to Pi Zero that would be useful for executing multiple requests at the same time. Server will check the condition of local devices constantly. If just recovered from Internet lost or power lost it should be able to get the recovered. After calculated the daily total energy consumption it will store to local storage unit for archiving. Every four hours the desired information will be uploaded to the web or front-end interface.

Criterion for Success

Our solution will be successful if it can accurately and instantly measure the power consumption and usage of any identical room in ECEB and display it on the screen set somewhere on the 1st floor in this building. Even though regular maintenance of the devices such as change of batteries for local power of the sensors may be required, the sensors and communication system itself should have the ability to overcome normal emergency circumstances such as the ability to keep recording and storing the data when building was powered down. In addition, as was required on the pitch day, the whole system should be able to last 5 years. The end goal of our design is to help people understand directly how many power each room is consuming and that if there’s a tiny error in the powering system, such as a short in the labs, it could also be obviously seen on the display on the first floor of the building.