Electrical Brain Surgeons
High Level Design

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Introduction

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Goals for the Project:

- Develop a device to measure power and power factor at a node in a smart grid network.
- Make this information available via the internet through wireless transfer of incoming data.

Problem Statement and Proposed Solution

Smart grids are electrical grid networks designed to provide energy in a more reliable and efficient manner. While smart grid networks are being considered as the wave of future due to their reliability, versatility and expected reduced energy wastes, there are still some challenges that impede their wide adoption. One of these big challenges is how to correct the power factor for better energy flow in large and complex smart grid systems. Some smart grid systems are so complex that it is hard to monitor/improve upon reliability and efficiency. Our proposed solution to this problem is to create a device that will measure power and power factor at different nodes in a smart grid network and make this information available via the internet. This will enhance the process of pinpointing exactly where improvement in a network needs to be made. If the power factor is below 1, a capacitive load needs to be added to the system to balance out the effects of the inductive reactance at the node. If the power factor is above 1, an inductive load needs to be added to the load to balance out the effects of the capacitive reactance at the node.

System Requirements

Voltage Measurement:

Our device will be powered by the power at the node we are measuring. The voltage will be passed into the microcontroller, which will measure the power at the node. Because the microcontroller can only accept a maximum voltage of 3.3V, the voltage from the node will be stepped down through a voltage divider.

Current Measurement: As we cannot directly input current into the microcontroller, we will have the current to be measured pass through a sense-resistor. This sense-resistor has a small and known resistance and thereby offers two advantage:

1. Since the resistance is small, the flow of current going through the sense-resistor is not largely affected.
2. Having made the current go through this sense resistor, a voltage difference is created across the resistor. This voltage can be connected to the microcontroller for measurements. In order to recoup the value of the current, the voltage

measured in the microcontroller is divided by the known resistance of the sense-resistor.

Alternatively, we can use a current sensor that we may connect into the microcontroller.

Power Factor Measurement:

In order to calculate the power factor at the node, we pass both the current and voltage signals into an interrupt pin of the microcontroller. The goal is to time when each of these signals crosses zero. When the signal crosses zero, the interrupt is activated. The delay between two interrupts gives the phase difference. Having this phase difference we can calculate the power factor, which is the cosine of this angle.

System Block Diagram

Overall System

The overall system takes in voltage and current from a node, and measures the power and power factor at that node. The system then makes the data available by the transmitting the data to a database on a web server. The system will be powered by the power available at the node being tested.

Subsystems

The overall system is broken down into five subsystems. The first subsystem uses a voltage divider to step down the voltage from the node. This requires only two resistors. The second subsystem measures the current, and will consist of a single resistor and two wires. The voltage will be passed through this resistor. The microcontroller will then measure the voltage on each side of the resistor by connecting wires to either side of the resistor on the breadboard. The third subsystem is a phase meter that will measure the phase angle for both the voltage and the current. The cosine of the phase difference between voltage and the current gives the power factor. The fourth subsystem will be written in C and requires the senior design kit board to download the program to the microcontroller. The fifth subsystem involves the transmitting of the data via WiFi. This requires the ESP8266 Model 1 and a computer with a web server/database.

Future Enhancement Requirements

In the future, we would like the further improve our project by creating two variable loads to fix the power factor: an inductive load and a capacitive load. If the power factor measurement is below 1, we will connect the capacitive load to the node to correct the problem. If the power factor measurement is above 1, we will connect the inductive load to correct the problem. The idea is to keep the power factor as close to 1 as possible.

Wifi Considerations

Using WiFi to make the power information available over the internet is an important part of the project. We plan to use a single wifi network to transmit the data. This will require a WiFi transmitter that will be connected to the microcontroller. The microcontroller itself will work as the heart of the system. As the microcontroller receives input from the node, it will perform the necessary calculations and feed out the results to the wifi transmitter. Each independent measurement will consist of the power and power factor to be transmitted via WiFi.

The measurements will be sent to a web server containing a database for the information. Figure 1 shows the preliminary diagram for the data flow. For this project, the ESP8266 Model 1 can do all of the required functions necessary.

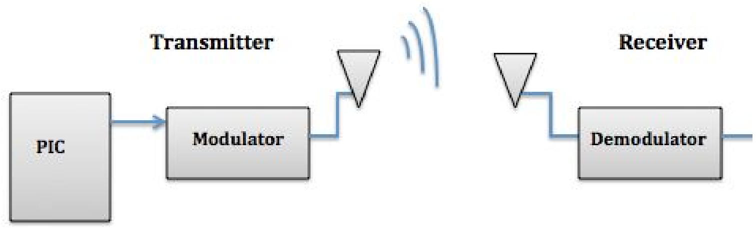

Figure 1. Diagram of Data Flow

High Level Design Decisions

The first subsystem reads in the voltage from the node and steps it down to a voltage that can be accepted by the microcontroller. The microcontroller can take a maximum of 3.3V. The second subsystem measures the current. This is necessary to compute the power factor. The system will consist of a single resistor and the voltage will be passed through this resistor. The microcontroller will then measure the voltage on each side of the resistor. Using the equation $\frac{(V_1 - V_2)}{R}$, we compute the value of the current.

Alternatively the current will be measured with a current sensor attached to the microcontroller. The third subsystem is a phase meter that will measure the phase angle. This is necessary to compute the power factor. The fourth subsystem is the code that will be downloaded into the microcontroller to measure and gather data on the power and current measurements, and to compute and report the power factor. The code will be written in C, similar to the past assignments. Lastly, our final subsystem involves the transmitting of the data via WiFi. Using the ESP8266 Model 1 and a created web server, data will be transmitted from the microcontroller to the web server and stored in a database.

Open Questions

We are currently unsure of the following:

- How to create a server and database to receive data from the microcontroller
- What other factors do we need to consider so that we can build a very robust system that takes into account several nodes?
- How can we organize the data transmission from all the nodes to avoid any data corruption?
- What should the device tell the node depending on the incoming data from other nodes and vice versa?
- Where are the most practical places where we could apply this device?
- Considering a big interconnected systems, where would the placement of device be most practical? or what are the most important nodes of an electrical grid?

Major Component Costs

Our project mainly involves designing circuits for the system, such as the voltage divider, and writing the code to be downloaded into the microcontroller. The only cost for the project is the purchase of the ESP8266. Because our device will be designed the measure any generic node, for our demonstrations we can simply use the power from a power supply. We can find the needed resistors for the voltage divider and the alternative to measure the current in the Senior Design closet. We can use a current sensor from Dr. Ken Sauer's lab. As we are not completely determined on the needed wifi components, we will purchase them next semester.

- ESP8266: $3.49

Conclusions

By the end of the fall semester we will demonstrate that we can measure voltage, current and power factor using a microcontroller. In the Spring semester we will work on the wifi communication aspect of the system to send the measurements online. A possible expansion of the project consists of the disponibility of variable capacitive and inductive loads to correct the power factor.

References:

- http://www.allaboutcircuits.com/textbook/alternating-current/chpt-11/calculating-power-factor/
- http://www.amazon.com/ESP8266-ESP-01-Serial-Wireless-Transceiver/dp/B010N1ROQS/ref=sr_1_7?ie=UTF8&qid=1449723397&sr=8-7&keywords=ESP8266