جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Electrical Engineering

Spring 2019-2020

Senior Design Project Report

Smart meter

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical Engineering

Team Members

	Student Name	Student ID
1	Feras AlKhowaiter	201202578
2	Majed Aldohailan	201500975
3	Abdullah Aldagani	201502518
4	Abdullah Alqarni	201302190

Project Advisors:

Advisor Name: Dr. Chedley Yahya

Abstract

This report will show the procedures that we carried out to implement a “Smart Power Meter” as our senior design project. Our system design can compute the power and energy consumed from different loads, and can shut down loads based on the concept of dynamic pricing and price limit. Also, the system will provide easy coordination between the electrical company and the consumer. This will be achieved by creating a user-friendly interface that can be accessed wirelessly through Wi-Fi.

Table of *Contents*

List of Figures

List of Tables

1. Introduction

1.1 Project Definition

In this project, we will implement a smart meter that will compute the power consumption and communicate with the control office over the internet. Also, it will have the capability to disable some of the loads based on the current electricity price and demand.

1.2 Project Objectives

· To compute the consumed energy from the house.

· To calculate the accumulated cost of the consumed energy.

· To update the customer with the current cost.

· To provide the electricity bill to the customer and to the company.

· To disable the least necessary loads in the house to reduce the consumed power.

1.3 Project Specifications

· Provide a two-way communication between the company and the user using the internet.

· Deal with the dynamic pricing.

· Ability to disconnect loads during peak times.

1.4 Product Architecture and Components

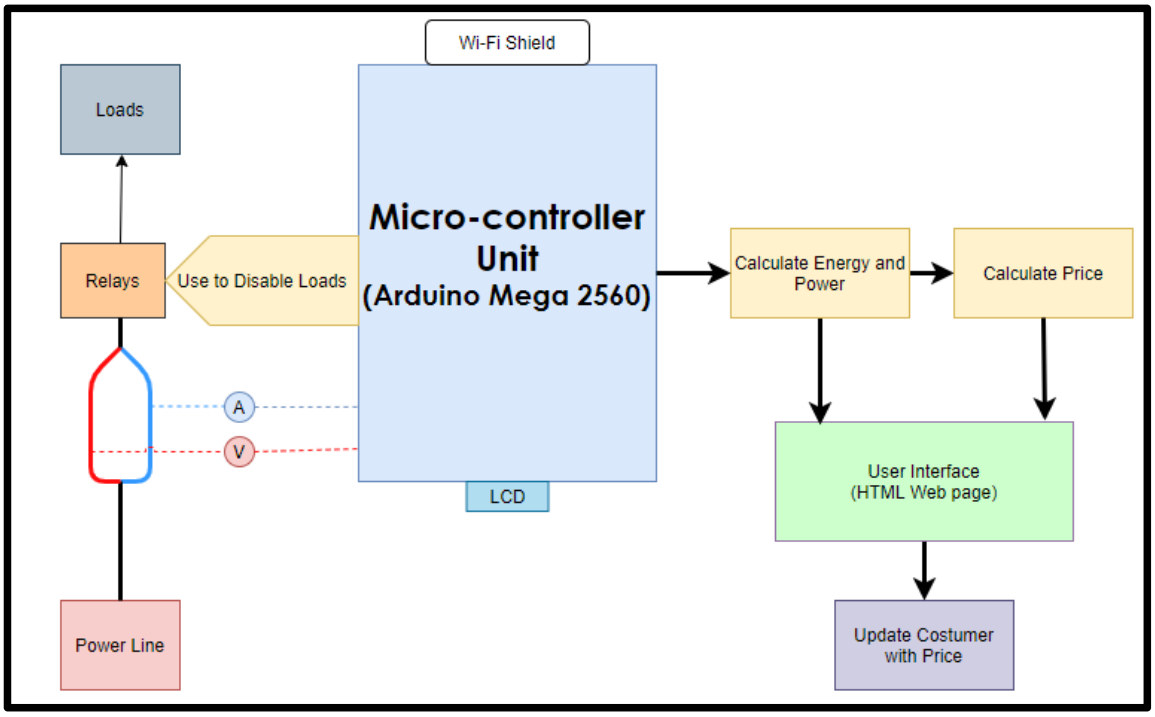


Figure 1: Product Architecture and Components

Components: -

- Micro controller: Arduino
- Wi-fi shield
- Current transformer
- Voltage transformer
- Relays
- Load (heater, light bulbs…)
- Wires
- Power factor module

1.5 Applications

This product is very useful to reduce electricity bills, so this product can be used in houses, hospitals, companies and any place which has electricity and needs meter.

2. Literature Review

2.1 Project background

Nowadays, the demand for electricity is rapidly increasing around the world, and most specifically in Saudi Arabia. In fact, a study that was conducted three years ago, and published by the Saudi Press Agency (SPA), recorded an unprecedented energy consumption in the Kingdom. On August 31st, 2014, the electricity usage during the peak time reached 56.500 MW, that's an increase by 7.7% of the recorded values of the summer of 2013.

Moreover, studies showed that Saudi Arabia is one of the highest countries in the world in regard to electricity demand, where the per capita usage is equal to more than double the international average, with an annual increase of 5.5%. In addition, a recent study that was carried out back in October of 2016 estimated the per capita usage/month in Saudi Arabia in the entire year of 2015 to be 779 kWh.

On the other hand, although this high demand might be due to the economic growth, industrial transformation, urbanism, as well as the constant growth of population, a big part of this extremely high usage can be related to the wastage, and the inefficiency of electricity consumption especially in houses. As a matter of fact, this forced the Electricity Company to expand its power plants, which cost hundreds of billions of Saudi Riyals.

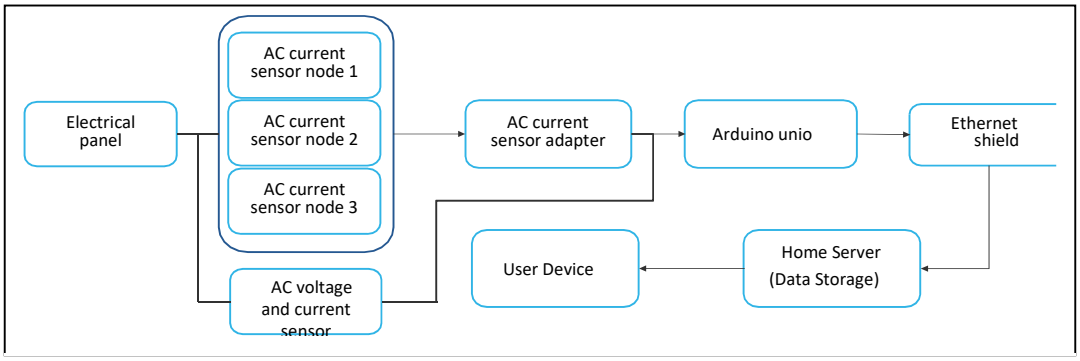
2.2 Previous Work

Title 1: Smart sensory energy metering

Introduction:

SSEM (Smart Sensory Energy Metering) is an electronic device that records consumption of electric energy and allows customers to program how and when their home uses energy.

Block diagram:



Functionality:

In this project they use A/C current sensor, AC current adapter, Sensor Controller (Arduino mega), Ethernet shield, Voltage and Current sensor and server as showing in figures 1 As its show in the diagram where each hardware will be. And with the electrical panel which contain several circuits switch each switch control of some part of the home that use electric current, they connected each switch with the sensor and will allow as to read the current that move in that wire that come out from the switch to a room, the AC current sensor will be install inside the electric panel and connect the sensor with wire. The sensor will be connected to the adapter shield by wire, each AC current sensor has it won channel that provided by AC current sensor adapter. The Ac current sensor adapter shield will be connected to the sensor controller by small pins “male pins “come from the adapter shield connect to the female pins on the sensor controller node. The sensor controller node will be programmed to convert the analog value that came from sensor to digital, the sensor controller will be connect to the Ethernet shield by long wire or it can be connect by the small pin that are been on adapter shield. The Ethernet shield will be connected to the sensor node, at same time the Ethernet will be connect to the laptop or PC that are work as home server. The home server will include to part server and client the server is web server include the web control, receiving the data that are collect it to the webserver database , the database c be design by MySQL and connect it to the webserver , the databases will have many thing such as cost of the electric usage , time of electric usage , number of room , the value of the current .The user device “Client “it is a web page will be make it be the HTML and JQuree the

client will be able to choose many option from the webpage such as select the limit of cost and time and for each room that connect to the system, there will be an application for the user using just to showing the electric usage on live time, and receiving the message when there is high electric usage. The hole part will be connected to each other and work as one system.

Title 2: IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid

Introduction:

Smart grid plays an important role in our current society and in our networks. Smart meters play a vital role. Smart meter provides immediate monitoring of reliable status, automatic information collection, user interaction and energy control. It also provides a double flow of information between consumers and suppliers, provides better control and efficiency. It also provides real-time consumption information and provides power control. As long as the customer's maximum load demand exceeds the maximum value, the electricity supply to customers will be separated with the help of an intelligent power meter. In an ideal environment with normal workload conditions, the smart meter has a service life of 5 to 6 years. In this project, the use age of the smart meter with IOT technology is introduced. The IOT-based power meter system consists mainly of three main parts, which are remote control, Wi-Fi and theft detection part. When there is an error or theft, the theft detection sensor detects the error response and the circuit according to the information it receives. The console plays a key role in the system to ensure that all components work well. Therefore, Internet of things can improve the performance and efficiency of the smart grid mainly in the three phases.

Block Diagram:

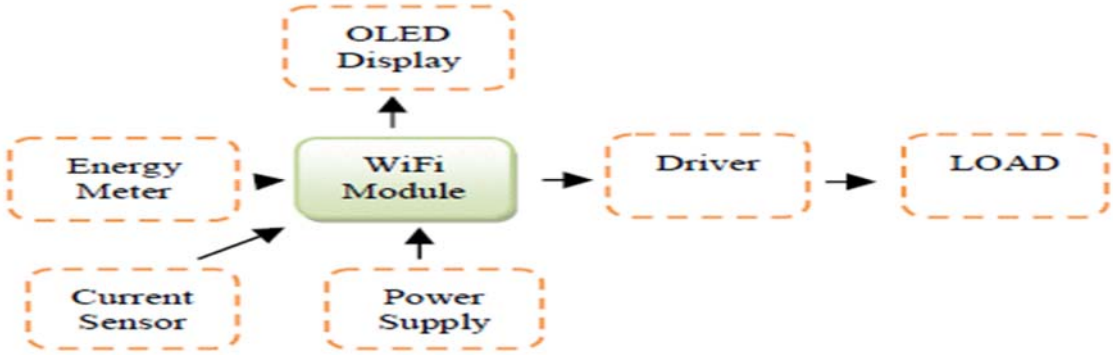


Figure 3: IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid.

Functionality:

The proposed system is cost effective and compact. Therefore, the premium becomes much easier. In this proposed system, the power meter is connected to the microcontroller through an opt coupler. The OLED screen is also connected to the system. In the controller circuit, ULN2003 is used to drive the relay to change loads. The current sensor is also equipped to determine energy theft. Figure 3 illustrates the

functional block diagram of the proposed intelligent monitoring system. The main functional unit of this system is discussed. The Wi-Fi module is used here and is programmable with an 80 MHz microcontroller. Then, the OLED screen used here that does not require backlight. You can illuminate the screen with high resolution. Then, the optical coupler detects the calibrated lamp of the energy meter and sends its output to a microcontroller. The optocoupler mainly produces infrared light and a semiconductor image sensor is used to detect the emitted infrared radiation. The Wi-Fi module is programmed using the Arduino IDE software to calculate the pulse of the power meter. The optocoupler pulse sensor and sends the data obtained to the cloud by microcontroller. The lamp blinks 3200 times in one unit. The LED flashing of the energy consumed in the units is calculated with the unit cost. Monitoring is carried out at each interval. The system also provides power theft with the current sensor connected to the system. Therefore, the system does not imply providing a less human error.

.

Title 3: Design and Implementation of the Smart Meter in Vehicle to Grid

Introduction:

Today, EV is an important area for researchers due to its attractive properties of reducing the use of gasoline and greenhouse gas emissions compared to conventional compounds. In this paper, the authors described that electrical vehicles achieve this by using a larger capacity battery pack that can be recharged using the power provided by the power grid. If the diesel generator of the electrical vehicles is considered, there should be a bi-directional smart meter that not only measures the charged car but also measures the energy saved in the network. The smart meter is the interface between electric cars and the network. It has two special functions compared to the traditional meter. The smart meter has a bidirectional scale and a bidirectional connection compared to a conventional meter. You can judge the direction of the energy consumption of a system by the different phase between the current and voltage wave in the mains. You can calculate the energy consumption or import power of the car. Basically, the smart meter is the interface between the network and the electric car. You can achieve a change of address between the electric vehicle and the network through GPRS. In this document, they provide a detailed description of the hardware and software.

Block diagram:

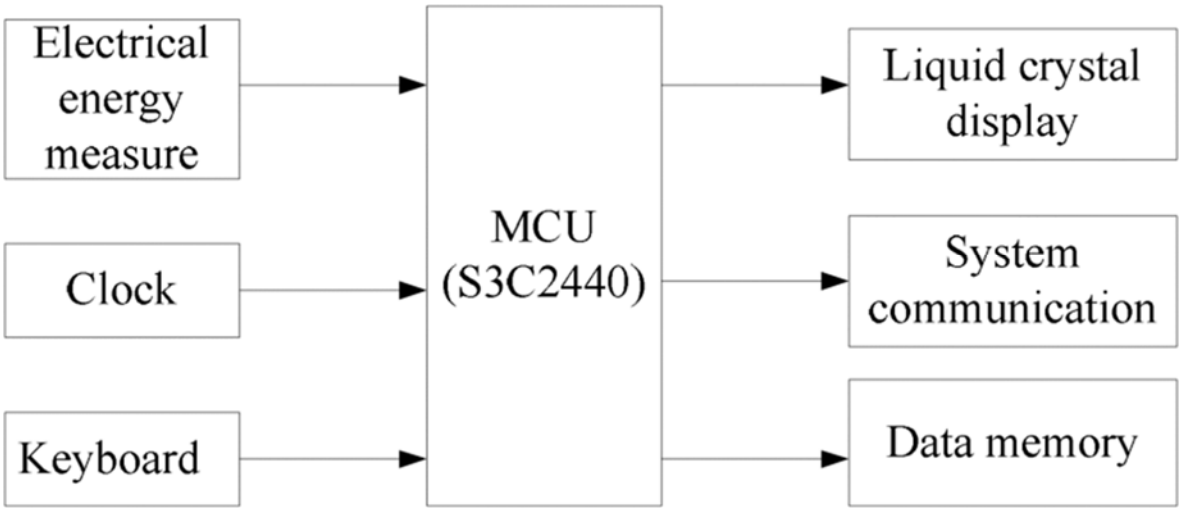


Figure 4: Design and Implementation of the Smart Meter in Vehicle to Grid

Functionality:

The smart meter consists of a microprocessor controller (MCU) and an external interface circuit, which includes the measurement of electrical energy, clock, keyboard, LCD screen, system connections and data memory. The integrated circuit measures

various parameters of the electrical signal, such as active, reactive and visual energy, peak values, signal duration, temperature, etc. After the measurement, the signal is transferred to the MCU, which is primarily responsible for the process here. This circuit designed in this document has an input for current sampling and an input for measuring voltage. Then, Samsung IC is designed for mobile devices and general applications with a compact solution, low consumption and high performance. Its low power and simple and stable design are especially suitable for cost and energy sensitive applications. It is based on a new bus architecture known as Advanced Microcomputer Engineering. Then the communication module is the core part of the system. The system uses two main communication methods: RS485 and GPRS connections. To solve data in large quantities, save the function in case of power failure and other problems, the smart meter designed with 2M*32-bit flash memory. The data and program preservation requirements can be saved, without loss of data in case of power failure, and ensuring the speed meter reading. It has unlimited meter reading and writing functions, and is low in power consumption.

Title 4: Smart Metering and Functionalities of Smart Meters in Smart Grid- a Review

Introduction:

The Smart grid application may be a possible solution to meet the growing demand for energy use and the increased use of smart meters. The intelligent measurement application and various algorithms also have the ability to make defects in the energy, isolation and recovery system with high precision. There are many equipment and energy measurement solutions available to address and control energy usage problems. The capabilities and functions of smart meters are currently used commercially by several comprehensive utilities. One of the objectives of this article is to identify and review the functionality and functionality of commercially implemented smart meters. Smart meters are powerful digital displays and capabilities to record how much energy is consumed and when this information is automatically transferred to the meter's data management system (MDMS) for further processing and storage. To maintain interoperability between different smart meter providers and MDMS solution providers, data collection and storage standards and data communication standards must be followed. The other objective of this article is to review the literature on intelligent metadata data structures, information flow, measurement data management solutions and

data use. To capture the rapid development and deployment of smart meters when trying to identify emerging opportunities, this document provides an overview of smart meters and the functions of smart meters in the smart grid and associated systems.

Block Diagram:

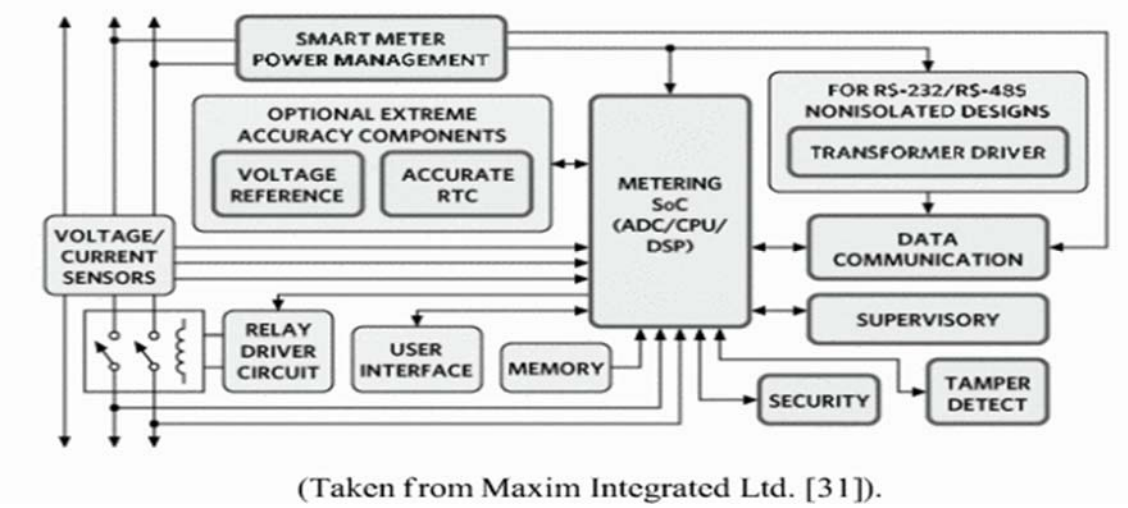


Figure 5: smart metering and functionalities of smart meters in smart grid- a review block diagram

Functionality:

Smart meters include a range of hardware, software and calibration systems. Metrics, security and communications are essential elements of smart meters. The Figure 5 shows a block diagram of an intelligent scale showing the building blocks of an integrated solution for intelligent measurement. An intelligent meter system may include: accurate real-time clock (RTC), data communication module, chip measurement system (SoC), security module, power management system, monitoring unit, tamper detection, power adapter and voltage reference (VREF). The Smart Device Center is based on an SOC processor, which includes the architecture to support measurements. The analog front end of the meter consists of digital converters that support differential inputs. The integrated gain phase provides gains for low production sensors. The hardware multiplier (HW) can be used on the SOC chip to further accelerate the intensive operations of mathematics while calculating energy. On the other hand, the program supports the calculation of several parameters. RMS current and voltage, active and reactive energy, power factor and frequency are the main parameters calculated during energy measurements. The measured and calculated data are stored by the smart meter and transmitted according to the different standards required by public utilities.

Title 5: Implementation of Smart Meter Working as IEEE1888-6LoWPAN Gateway for the Building Energy Management Systems

Introduction:

When building the power management system, Smart Meter (SM) plays an important role in helping users feel active and determine energy consumption. As a result, multiple efforts have been made to improve the function of this device in order to contribute to the reduction of energy consumption towards a green economy and sustainable development. In addition to SM, other protocols have been developed to achieve intelligent, convenient and safe management and control between buildings or building blocks. With the growing growth of devices connected to the Internet, the Internet of things, the integration of millions of devices into the Internet IPv4 is not the best option. Therefore, IPv6 is designed to solve this problem. IPv6 allows more Internet-based devices. IPv6 is more complex than IPv4; therefore, devices usually consume more energy. Based on previous concerns, the low power IPv6 protocol was developed for the wireless personal area network to reduce consumption.

Block diagram:

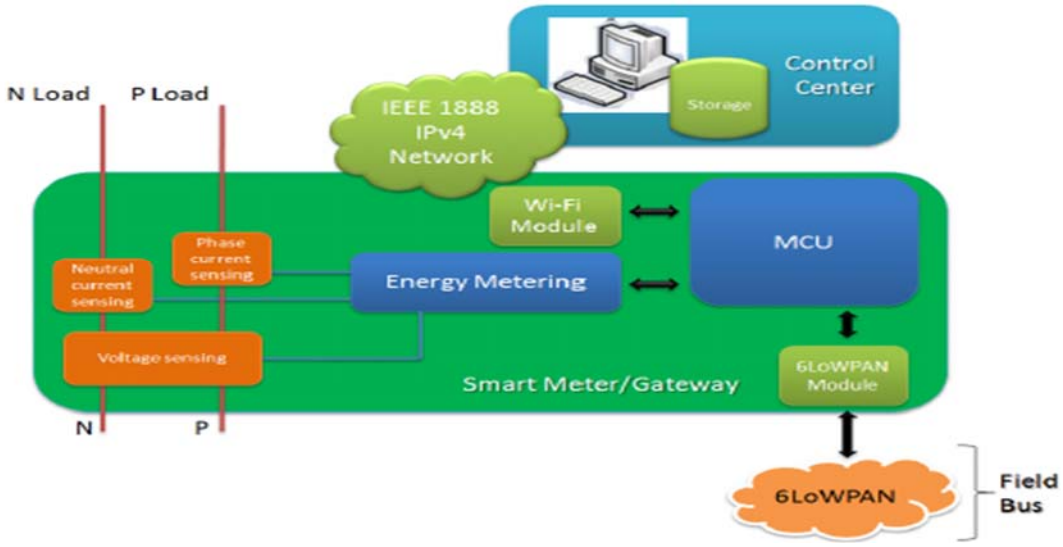


Figure 6: Implementation of Smart Meter Working as IEEE1888-6LoWPAN Gateway for the Building Energy Management Systems

Functionality:

The form represents the system architecture, including SM, which acts as a GW to transfer data from an FB network to storage in the control center through a Wi-Fi connection. Communication with small sensors or actuators that use the FB is a built-in FB Internet device that packages IEEE packages and communicates with storage and applications via Wi-Fi. The microcontroller acts like the SM CPU and is connected to measure the IC power using the SPI connection. The combined power processor was used to calculate the amount of electricity from the specified AC voltage and current. The SM Wi-Fi module is used to transmit electricity consumption and FB data to control the center using the standard IEEE protocol. It provides wireless connectivity with complete and independent IP, but communicates with the CPU through a simple USART port. Therefore, a module is designed in a small form, which consumes very little energy. The FB network has some client nodes that integrate small temperature sensors and can transfer temperature data to the server node connected to the MCU through a USART connection.

Title 6: Implementation of Smart Meter

Introduction:

In our actual project, we are going to implement a smart meter that will compute the power consumption. Once it is done, then next it will communicate with the control office over the internet. Also, it will have the capability to disable some of the loads based on the current electricity price and demand. Basically, our project is majorly based on a system in which we can save the unused power from the system. Like if we talk about the metering then it will first measure the used power of the system and transfer the whole data to the nearest office for the billing. And as this device is called smart so it has a smart option like it can disable the load if the demand is increasing from the main supply.

Block Diagram:

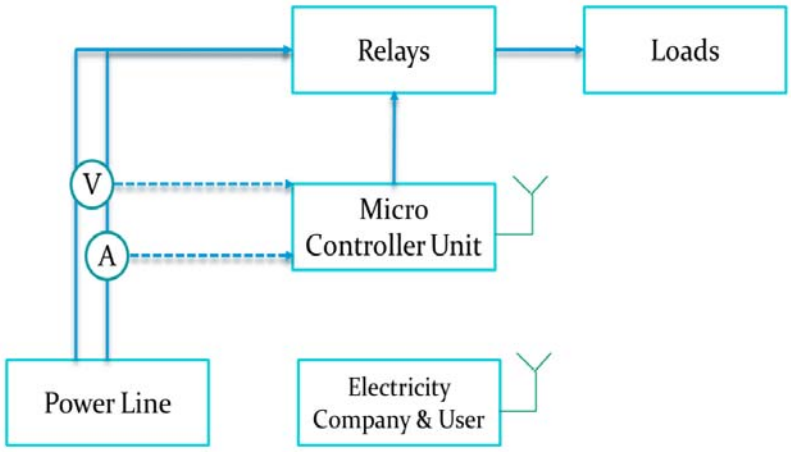


Figure 7: Implementation of Smart Meter

Functionality:

Basically, smart meter has a simple flow diagram as shown in figure 7. First, we will connect two measuring meters. The voltage and current entering the system will be measured to compute the consumed power through a microcontroller. Then, using these measurements and the current electricity price, the bill will be calculated. Meanwhile the user will be updated with the current price and bill. In addition, the price will increase during peak times to encourage users to reduce their consumption. However, if the user didn't comply, some of the uncritical loads will be switched off. So, this is how our circuit will flow on hardware like our first major part will be the measurement system and then it will transfer the recorded data to microcontroller which will calculate the required bill according to the recent tariff. Basically, the tariff prices go changing in peak and normal duty hours. So, this is the main simple smart meter and the upper discussed cases are the practical applications of this project.

2.3 Comparative Study

Projects	1	2	3	4	5	Our project
Smart meter	Yes	Yes	Yes	Yes	Yes	Yes
Communication GSM, Wi-Fi	Internet shield	Wi-Fi	RS-485 GPRS	GSM	Wi-Fi	Wi-Fi
Billing	Yes	No	Yes	No	No	Yes
Energy consumption monitoring	Yes	Yes	Yes	No	Yes	Yes

Table1: comparative study

We can see that from the previous projects the nearest one to our project was smart sensory energy metering cause it's a smart meter it also has a communication way and its energy consumption monitoring. The other projects have a simple relationship with our project but Almost most of them have loads, relays, voltage and current sensors so we considered that as a similar project.

3. System Design

3.1 Design Constraints

Standards

- ANSI C12.1-2014. American National Standard for electric meters-code for electricity metering.

- Table 2: list of Constraints

Economically	Available budget 1500 SR.
Sustainability	Product lifetime: expected 20 years.
	Temperature can affect the phase shift of the transformers leading to in correct readings.
Health and Safety	The system must be closed.
	Requires fire extinguisher and fuses during experimentation.
	The electrical engineering labs in KFUPM are limited to 2.5A.
Socially	Requires high security for communication.
Manufacturability	The materials used are available in the market (except the current transformer) and can be easily constructed and programmed.

3.2 Design Methodology

The way we acquired voltage readings is using a voltage transformer with voltage ratio 220V: 3V by connecting the secondary windings to a circuit before connecting it to Arduino input. Open Energy Monitor website guided us through interfacing the transformers outputs with the Arduino.

1.1.1.1 Components

1- Voltage transformer with voltage ratio 220V: 3V.
2- 22k Ω, (3x) 100k Ω Resistors.
3- 10 µF Capacitor.

Finally, after doing some research we agreed to use a split core current sensor shown in Figure 8 with a ratio of 100A: 50mA. This type of current transformer was the closest to our requirements.

Figure8: Current Transformer Split Core

3.3 Product Subsystems and Components

3.3.1 Subsystem 1

Voltage reading: -

Acquiring the voltage readings is the first step in building a basic power meter. However, some of the power meters that we came across, during the research stage, did not advice to use voltage readings, instead, they only preset a specific voltage level that will be constant throughout the whole process of calculation. Even though this step would be very significant in saving time and efforts in both implementation and calibration stages, we chose not to use it in our design for some accuracy reasons. Moreover, we came across some designs that advised the use of power adapters as voltage transformer As we stated earlier, in order to calculate the power in the Arduino, both current and voltage readings must be obtained previously.

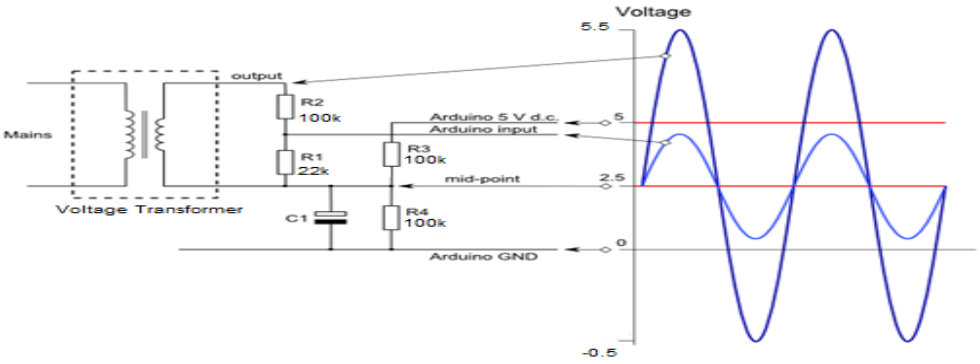


Figure 9: Voltage Measurement Circuit

3.3.2 Subsystem 2

Current reading: -

Adding a bias to the current signal using a voltage source created by voltage divider connected across the Arduino's power supply because Arduino only accept positive values.

Also, Arduino can only deal with voltage so a small resistor was added so that when the secondary current of the transformer pass through its voltage will be produced and measured.

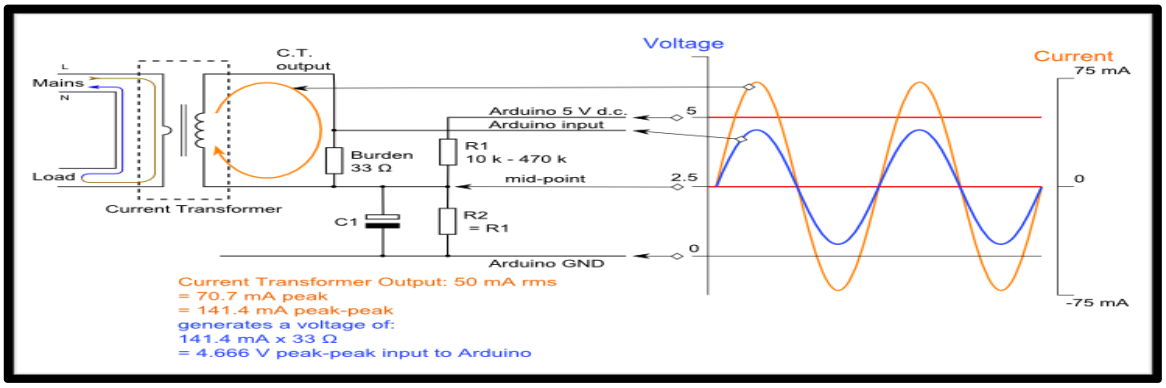


Figure 10: current reading diagram

During the research stage we came across multiple of methods that is used to get the current values. One of which was using current transducer. This option was not very optimal since it required power supply as well as its core was not of the split type that would make the connection easier.

3.3.3 Subsystem 3

Initial Web Page: -

Integrating the HTML Code to the Arduino Code:

After developing our final code for the web page, we had to integrate it into the overall Arduino code for the entire system. This was by no means a straightforward process to perform because of the many differences between the two languages and their constructions.

We can see in figure 11 the rates of the energy, the real power and the bill rates in the interface that we made.

Unfortunately, the Wi-Fi module broke and we could not get a new one due to the Covid-19 outbreak. Therefore, we had to find a new solution; and that is by keeping the Arduino connected to a PC that is connected to a Wi-Fi and using the internet through it. Next, we used an app called 'Blynk' as the interface for the user as seen in the figure 11.

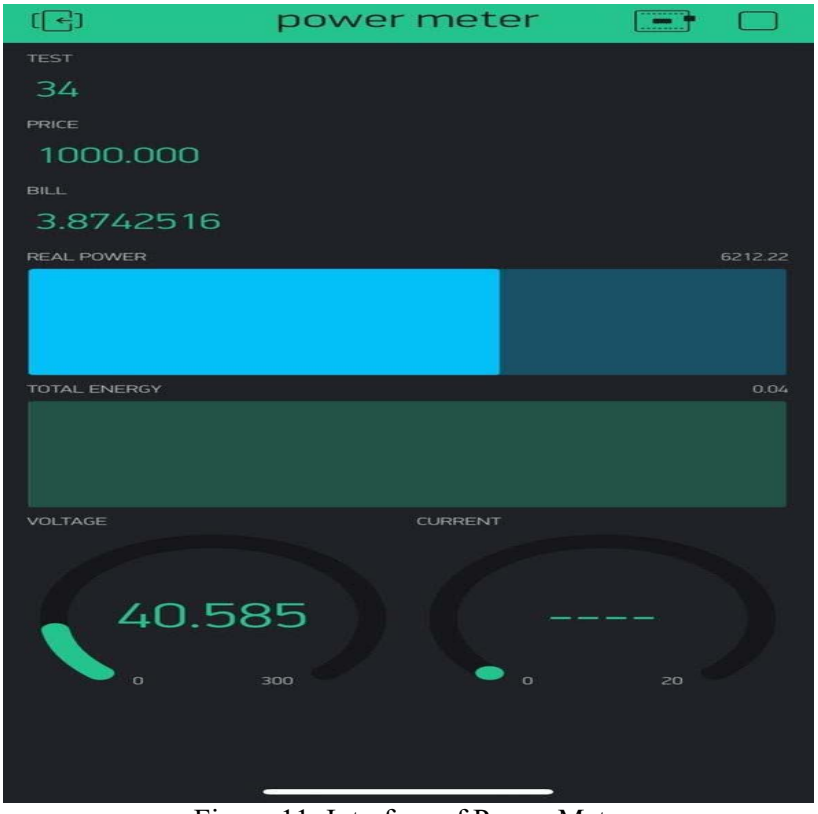


Figure 11: Interface of Power Meter

3.3.4 subsystem (4)

Power factor:-

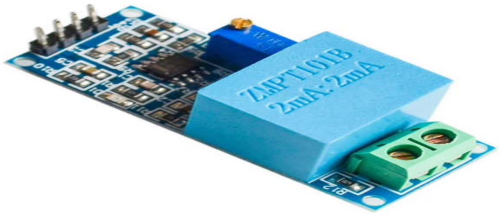


Figure 12: power factor module

This module is very useful for electrical projects. It has many applications such as, measuring AC voltage, sensing overload current, testing equipment and relay protection and measuring the power factor.

In figure 13, you can see the ZMPT1014 module diagram.

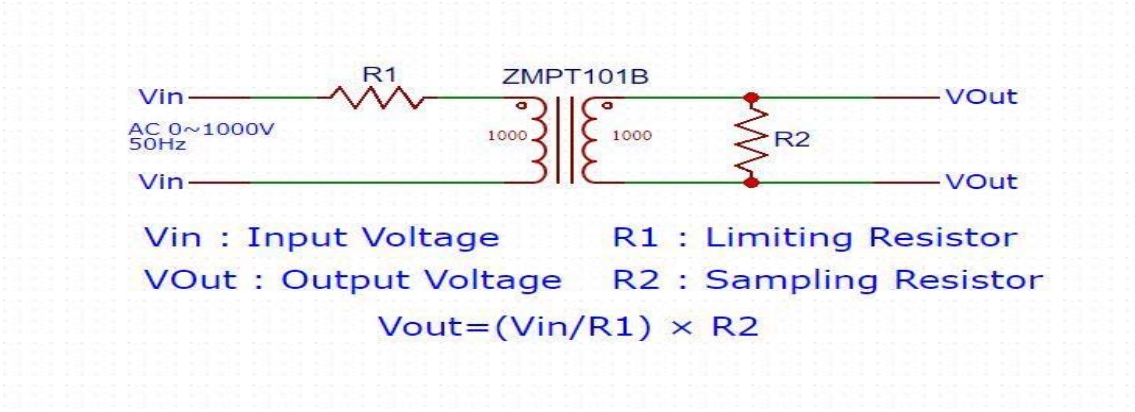


Figure 13: ZMPT1014 module diagram

Because of unknown circumstances the module has arrived but DHL returned it but there is a way to calculate the power factor by using the equations below.

```
I_rms = sqrt(I_rms/samples) * I_ratio;
V_rms = sqrt(V_rms/samples) * V_ratio;
P_apparent= I_rms*V_rms;

PF=P_real/P_apparent;
```

3.4 Components: -

Relays:

A relay is an electrical switch that operates using the principle of either electromagnet or solid state. There are many types of relays regarding the pole and throw. The pole is a part of the relay that controls the circuit by connecting it to the throw by the help of the electromagnet. These types are: single pole single throw (SPST), single pole double throw (SPDT), and double pole double throw (DPDT).

In our project, we used multiple SPDT relays as shown in Figure 14. This relay is Normally Closed (NC).

Also, this relay used to control 4 loads.

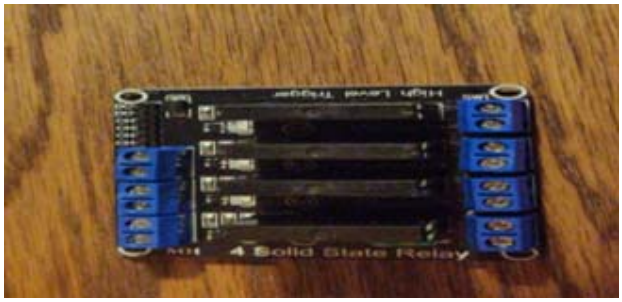


Figure14: SPDT Relay

Results: -

At this time, we couldn't test the relays to find the results.

LCD: -

In our project, we had to add LCD. The LCD stand for Liquid Crystal Display. There are many types of LCDs, but the one we were concerned about is the 16x2 LCD, which displays 2 lines each with 16 characters. We preferred this one over the other displays such as 7-seqments and other segments LEDs. The reason is that we can easily program it with the Arduino which allows us to display both numbers and letters in addition to the symbols.

And we could show the power, energy, bill and the price in the LCD below. And it shown in figures 15 and 16.

Figure 15: Price and Bill in LCD

Figure 16: Power and Energy in LCD

3.5 Implementation

The current measurement circuit is similar to the voltage measurement circuit where we added a DC bias because Arduino only accepts positive values. However, the difference between the two circuits is the fact that Arduino deals with voltage measurements only. Hence, we added a small resistor called "Burden" so that when the secondary current of the transformer passes through it, voltage will be produced and then measured using Arduino.

There will always be a current flowing in the primary side inducing current in the secondary side regardless of load existence. For this reason, a burden resistor is required.

Implementation Process: -

- Making sure that the Arduino can measure the voltage of the system.
- Measuring current from a system.
- Build a code that computes the power and energy consumed.
- Applying the dynamic pricing concept and bill calculation.
- Communicate wirelessly with the microcontroller and change the pricing.
- Display the information on Liquid Crystalized Display (LCD) screen.
- Develop the loads
- Calibrate the system and compare it to other products.

3.6 Future work: -

- Adding excel to website
- Having SD card
- Results after using relays

- Implement industrial design
- Power factor module

4.Final Prototype:

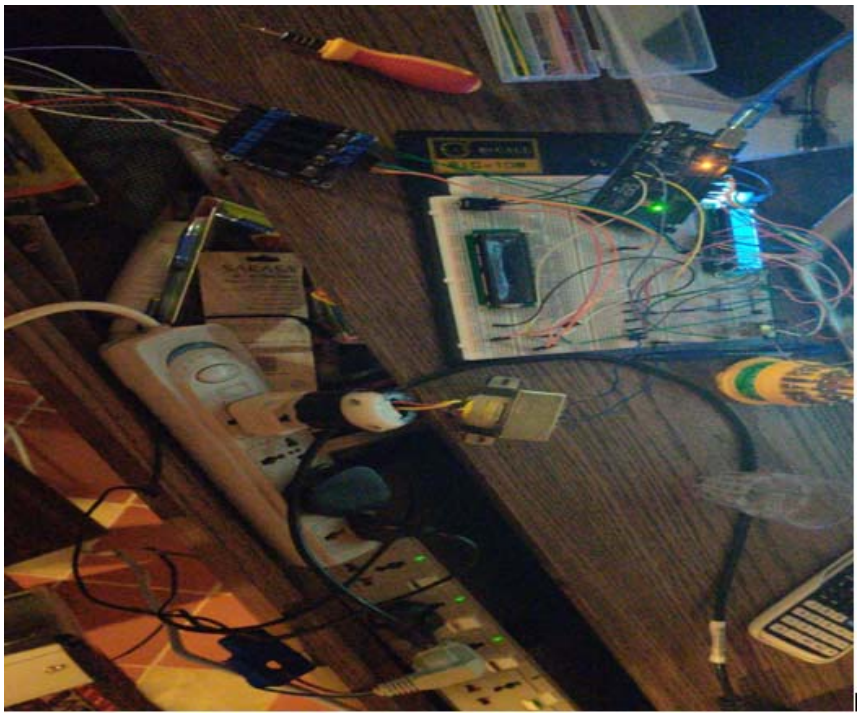


Figure 17: Final Prototype of the Smart Meter

The expected work in the future regarding the prototype is adding more than one load. We can see in the video that we have only one load which is heater but our plan to have more than one and put them in a designed box to make it look organized. Also, connecting the relays to see the results after.

5. Challenges and Decision Making

We tried to add excel to the website, but adding excel to website didn't work because we need an SD card slot that is attached to the Arduino. Unfortunately, the module we needed we will not receive it until mid-May. The other challenges that everyone has faced regarding the situation that the world facing this time. Also, due these difficult times we have faced a number of problems to complete and finish our senior project. COVID-19 has played a giant role in preventing the production of our final project. Because of COVID-19, we couldn't meet as a group, we couldn't have our parts that we ordered online due the lockdown of the air traffic, COVID-19 played a role in challenging us to proceed in continuing our project any further step.

6. Budget

The budget found as expected and not expensive, so economically the project budget is easy to be obtained.

- Table 3: list of Components

Components		Price
(3) Arduino Mega Microcontroller		310 SR
AC Voltage Sensor Module ZMPT101B		100 SR
Current Transformer		200 SR
Voltage Transformer		60 SR
Relays	5V 4 Channel Solid State Relay	40 SR
	Elegoo 4 Channel dc 5v Relay Module	40 SR
	SSR-40DA 40A Temperature Control Solid State Relay	40 SR
LCD		20 SR
Wires		100 SR
Breadboard		130 SR
Loads	Heater	100 SR
	Fan	50 SR
	Motor	100 SR
Total		1320 SR

7.Appendix

7.1 Appendix A : codes

Code:

```
#include <SPI.h>
#include <WiFi.h>
#include <LiquidCrystal.h>

byte skip = 254; // offset correction control


unsigned long t1;
unsigned long t2= micros();
unsigned long td;

float cumulative_Energy=0;          // In Joule
float price=1000;                   // In SR/kWh
float bill=0;                       // scaled down by /3600000 SR
float P_real=0;                     // Real power In Watt
float PF=0;                         // Power factor
float price_th1=2000;               // threshold of load 1  2000SR/kWh
float Bill_th1=10;                  // threshold of load 1 10SR
float price_th2=3000;               // threshold of load 2 3000SR/kWh
float Bill_th2=20;                  // threshold of load 2 20SR

// Offset found when there is no load.
float V_offset  = 514;
float I_offset  = 510.61;

// Current and Voltage ratios
// Conversion factor = ADC(5.0/1024.0) * Transformer Ratio(132.3/4.24) * Voltage Divider(122.0/22.0)
const float V_ratio = 0.84489;
// Conversoin factor =  ADC(5.0/1024.0) * Transformer Ratio(100.0/0.05) / Burden resistance(33.0)
const float I_ratio = 0.29593 ;


// Wifi information
char ssid[] = "house";      // your network SSID (name)
char pass[] = "12345678";       // your network password
int status = WL_IDLE_STATUS;
WiFiServer server(80);
while (!Serial) {

////////////////////////////////////////////////////////////////////////
void setup() {
lcd.begin(16, 2);

pinMode(30, OUTPUT);
pinMode(31, OUTPUT);

Serial.begin(9600);
```

```
;
 }

if (WiFi.status() == WL_NO_SHIELD) {
Serial.println("WiFi shield not present");
while (true);
 }

String fv = WiFi.firmwareVersion();
if (fv != "1.1.0") {
Serial.println("Please upgrade the firmware");
}

while (status != WL_CONNECTED) {
Serial.print("Attempting to connect to SSID: ");
Serial.println(ssid);
status = WiFi.begin(ssid, pass);

delay(10000);
 }
 server.begin();

 printWifiStatus();
}

////////////////////////////////////////////////////////////////
void loop(){
skip++;
if (skip%100==0) {
// Update the stored DC shift values
update_offsets();
}

// Compute Power and do bill calculations
compute();

// Disconnect/connect loads according to price limits
control();

// Print to website
printToPage();

//
if(skip%25==0)
{
  if(skip%2==0)
//
    screen();
  else
    screen2();
}
}
////////////////////////////////////////////////////////////////////////

void compute() {
// Variables initilized each cycle
float V_rms = 0;
float I_rms = 0;

float P_apparent = 0;
```

```
float Energy = 0;

// Variables to read analog inputs
int V_start = 0;
int V_sensor = 0;
int I_sensor = 0;

float  sump  = 0;
int samples;

t1 = t2;

//T=micros();
// 29 samples -> T = ~ 8.350ms for loop which is equavalant to 120Hz cycle m 0.287 seconds for 1000
samples
for(samples=0; samples<1000;samples++){

 V_sensor = analogRead(A0);
 I_sensor = analogRead(A1);


Serial.print(V_sensor);
Serial.print("   ");
Serial.println(I_sensor);

 float V = (V_sensor-V_offset);
 float I = (I_sensor-I_offset);

 sump  = sump +V*I;
 I_rms = I_rms + I*I;
 V_rms = V_rms + V*V;
}

Serial.print(V_sensor);
Serial.print("   ");
Serial.println(I_sensor);

T=micros()-T;

t2= micros();
td=t2-t1; // Period time in micro seconds

P_real = abs (sump/samples)* V_ratio* I_ratio; // to counter the out of phase issue we use absolute.

I_rms = sqrt(I_rms/samples) * I_ratio;
V_rms = sqrt(V_rms/samples) * V_ratio;
P_apparent= I_rms*V_rms;

PF=P_real/P_apparent;

Energy = P_real*td/1000000.0; // Energy consumed this cycle in Joule
cumulative_Energy = cumulative_Energy + Energy; // Energy consumed since arduino start Joule

bill = bill + Energy*price;


Serial.println();
Serial.print("Power Factor: ");
Serial.print(PF);
Serial.print("  Real Power: ");
```

```
Serial.print(P_real);
Serial.print("  Apparent Power: ");
Serial.print(P_apparent);
Serial.print("  Voltage rms: ");
Serial.print(V_rms);
Serial.print("  Current rms");
Serial.print(I_rms);

}

//////////////////////////////////////////////////////////////////////

void update_offsets(){
int V;
int I;
long sumV=0;
long sumI=0;
int samples=0;

//T=micros();
for(samples;samples<3700;samples++){  // 74 samples -> T = ~1.66 ms which is a full 60Hz cycle
 V=analogRead(A0);
 I=analogRead(A1);
 sumV = sumV + V;
 sumI = sumI + I;
}

//T=micros()-T;

V_offset= V_offset + ((1.0*sumV/samples)-V_offset)/16.0;
I_offset= I_offset + ((1.0*sumI/samples)-I_offset)/16.0;

Serial.println();
Serial.print("Voltage offset: ");
Serial.print(V_offset);
Serial.print("  Current offset: ");
Serial.println(I_offset);
}

//////////////////////////////////////////////////////////////////////
void printToPage(){

boolean f1= false; // if price changes set flag
boolean f2= false; // if price_threshold 1 changes set flag
boolean f3= false; // if Bill_threshold 1 changes set flag
boolean f4= false; // if price_threshold 2 changes set flag
boolean f5= false; // if Bill_threshold 2 changes set flag
WiFiClient client = server.available();
 if (client) {
   Serial.println("new client");
   String currentLine = "";
   String newPrice = "";
   while (client.connected()) {
    if (client.available()) {
      char c = client.read();
     Serial.write(c);
      if (c == '\n') {
          if (currentLine.length()==0) {
              client.println("HTTP/1.1 200 OK");
              client.println("Content-Type: text/html");
```

```
            client.println("Connection: close");  // the connection will be closed after completion of the
response
            client.println("Refresh: 30");  // refresh the page automatically every 30 sec
            client.println();
            client.println("<!DOCTYPE HTML>");
            client.println("<html>");

            client.println("<head>");
            client.println("<title>Smart Power Meter</title>");
            client.println("<style>");
            client.println("table, th, td {");
            client.println("border: 2px solid black;");
            client.println("border-collapse: collapse;");
            client.println("}");
            client.println("th, td {");
            client.println("padding: 10px;");
            client.println("text-align: middle;");
            client.println("}");
            client.println("</style>");
            client.println("</head>");

            client.println("<body>");

            client.println("<table style=\"width:40%\">");
            client.println("<caption><strong>EE411 Smart Meter Readings<strong></caption>");

            client.println("<tr><th>The Cummulative Energy is (kWh)</th></tr><tr><td>");
            client.println(cumulative_Energy/3600000.0);
            client.println("</td></tr>");

            client.println("<tr><th>The Bill is in SR</th></tr><tr><td>");
            client.println(bill/3600000.0);
            client.println("</td></tr>");

            client.println("<tr><th>Real Power (W)</th></tr>");
            client.println("<tr><td>");
            client.println(P_real);
            client.println("</td></tr>");

            client.println("<tr><th>Current price (SR/kWh)</th></tr>");
            client.println("<tr><td>");
            client.println(price);
            client.println("<form method=\"get\">");
            client.println(" New price : <input type=\"number\" name=\"a\" min=\"0\"
step=\"0.01\"></form>");
            client.println("</td></tr>");

            client.println("<tr><th>Threshold price for load 1</th></tr>");
            client.println("<tr><td>");
            client.println(price_th1);
            client.println("<form method=\"get\">");
            client.println(" New Threshold : <input type=\"number\" name=\"b\" min=\"0\"
step=\"1\"></form>");
            client.println("</td></tr>");

            client.println("<tr><th>Threshold bill for load 1</th></tr>");
            client.println("<tr><td>");
            client.println(Bill_th1);
            client.println("<form method=\"get\">");
```

```
            client.println(" New Threshold : <input type=\"number\" name=\"c\" min=\"0\"
step=\"1\"></form>");
            client.println("</td></tr>");

            client.println("<tr><th>Threshold price for load 2</th></tr>");
            client.println("<tr><td>");
            client.println(price_th2);
            client.println("<form method=\"get\">");
            client.println(" New Threshold : <input type=\"number\" name=\"d\" min=\"0\"
step=\"1\"></form>");
            client.println("</td></tr>");

            client.println("<tr><th>Threshold bill for load 2</th></tr>");
            client.println("<tr><td>");
            client.println(Bill_th2);
            client.println("<form method=\"get\">");
            client.println(" New Threshold : <input type=\"number\" name=\"e\" min=\"0\"
step=\"1\"></form>");
            client.println("</td></tr></table></body></html>");
            break;
          }
          else {
            currentLine = "";
          }
      }

    }
  }
 Serial.println(newPrice);
  if(f1){
   price = newPrice.toFloat();
   newPrice= "";
   f1 = false;
  }
  if(f2){
   price_th1 = newPrice.toFloat();
   newPrice= "";
   f2 = false;
  }
  if(f3){
   Bill_th1 = newPrice.toFloat();
   newPrice= "";
   f3 = false;
  }
  if(f4){
   price_th2 = newPrice.toFloat();
   newPrice= "";
   f4 = false;
  }
  if(f5){
   Bill_th2 = newPrice.toFloat();
   newPrice= "";
   f5 = false;
  }

  client.stop();
  Serial.println("client disonnected");
 }
}
```

```
////////////////////////////////////////////////////////////////

void printWifiStatus() {
 // print the SSID of the network you're attached to:
 Serial.print("SSID: ");
 Serial.println(WiFi.SSID());

 // print your WiFi shield's IP address:
 IPAddress ip = WiFi.localIP();
 Serial.print("IP Address: ");
 Serial.println(ip);

 // print the received signal strength:
 long rssi = WiFi.RSSI();
 Serial.print("signal strength (RSSI):");
 Serial.print(rssi);
 Serial.println(" dBm");
}
////////////////////////////////////////////////////////////////////////////

void control(){
if ((bill/3600000.0)>= Bill_th1) digitalWrite(30, HIGH);
else if (price>=price_th1) digitalWrite(30, HIGH);
else digitalWrite(30, LOW);


if ((bill/3600000.0)>= Bill_th2) digitalWrite(31, HIGH);
else if (price>=price_th2) digitalWrite(31, HIGH);
else digitalWrite(31, LOW);

}

////////////////////////////////////////////////////////////////////////////

void screen() {
 lcd.setCursor(0, 0);
 lcd.print("Price : ");
 lcd.print(price);

 lcd.setCursor(0, 1);

 lcd.print("Bill : ");
 lcd.print(bill/3600000.0);
}

void screen2() {
 lcd.setCursor(0, 0);
 lcd.print("Power : ");
 lcd.print(P_real);
lcd.setCursor(0, 1);
lcd.print("Energy : ");
 lcd.print(cumulative_Energy/3600000.0);
}
```

7.2 Appendix B: last Progress report for design course

" Smart Meter"

At this stage we have completed most of the work of this semester and I will show it in the steps below.

Step 1:
We have completed 80% of the circuit implementation using the Arduino and the transformers.

Step 2:
We have completed the program and the codes that we are going to use for this semester.

Step 3:
In these days, we are trying to calculate the bill for the customer and to show it in the LCD.

Step 4:
We have computed the current and the power.

7.3 Appendix c: last progress report for Assessment course

Title: Smart Meter	Advisor: Dr. Chedly Yehya	Design II (ASSE 3)	Spring 2020
Majed Aldohailan 201500975 (MA)		Project PLAN & Progress	
Feras Alkhowaiter 201202578 (F)		ProgRpt No. 4	
Abdullah Aldajani 201502518 (AD)		Plan updated (Date): April 25, 2020	
Abdullah alqarni 201302190 (AQ)		Instructor: Dr. Sadiq Alhuwaidi	

Period Highlight: 4 | Plan | Actual | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	Assigned To	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Write a plan	1	1	Ma , F	3	3	100%
Get AC voltage sensor module ZMPT101B	3	1	F	3		100%
Design subsystem 1 (measure V,I,P)	2	1	ALL	2	2	100%
Design HTML page and connect to Smart meter	3	7	AD	3		100%
Acquire wifi module	3	1	MA,AQ	3	4	100%
connect loads	6	2	AD, AQ			50%
Acquire relays	6	5	AQ			100%
Prepare midterm presentation	7	3	ALL			100%
Display data to end-user	3	1	F	3	2	100%
Design subsystem 2 (Calculate bill)	1	5	F	3	1	100%
Test subsystem 2	1	5	F,MA	3	1	100%
Implement industrail design	10	1	MA, AD			20%
Prepapre final report	12	2	ALL			100%
Prepapre final presentation	12	2	ALL			0%
Prepare project demo	13	3	ALL			50%
Submit Rpt/PPT/Brochure	14	2	ALL			0%

Periods (Weeks 1-15): 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Progress Details:	Issues (delay ...):
The HTML page is ready and we got all of the project's parts. So, most of the targets are completed. Also, we are done with final report	Due to COVID-19 we couldn't meet each other in order to work togher on the project. In addition, we couldn't implement the industrial design.

8. Conclusion

In conclusion, this report can explain the way to implement a smart meter which can compute the power, the energy, the bill and disconnecting loads. We start the report by giving the definition of the project and the objectives and applications. We aimed to evaluate the different steps and procedures that we took to obtain the voltage and current readings, the power calculations, the graphical user-friendly interface, Arduino coding, the load-disconnection techniques, and the LCD which provided an attractive display of the price and electricity bill. Most of the challenges that we faced in implementing the system was that some of the components didn't arrive in time and some of the components was ruined. Also, we took long time to implement the system in Fall semester. At the end of the Fall semester, we did a big mistake that we dissembled the circuit and I think some of the components was ruined because of that and this cost us the delay of reimplementing the system. At the end, the components arrived but due to the Covid-19 situation it was very hard to make the project in the way we want. The project couldn't cost us a lot. It should cost us around 1500 SR but it cost us around 1200 SR because we didn't buy the whole loads yet. Finally, we are very sad that we couldn't finish it. We always waited for a stress at the time of discussions or the time of showing the demo of the project but there is nothing to do. We must say thank you for taking care of us and make it easy for the whole students.

9. References:

https://innovatorsguru.com/zmpt101b/

(n.d.). Retrieved from https://forum.arduino.cc/index.php?topic=320818.0

(n.d.). Retrieved from https://forum.arduino.cc/index.php?topic=347984.0

Archived Forum. (n.d.). Retrieved from https://openenergymonitor.org/forum-archive/node/156.html

Archived Forum. (n.d.). Retrieved from https://openenergymonitor.org/forum-archive/node/156.html

Electrical Relay and Solid State Relays. (2018, February 11). Retrieved from https://www.electronics-tutorials.ws/io/io_5.html

OpenEnergyMonitor. (n.d.). Retrieved from https://learn.openenergymonitor.org/electricity-monitoring/voltage-sensing/measuring-voltage-with-an-acac-power-adapter

OpenEnergyMonitor. (n.d.). Retrieved from https://learn.openenergymonitor.org/electricity-monitoring/voltage-sensing/acac-component-tolerances

STEM, H. (2019, December 14). Hacking STEM Electroconductivity Meter. Retrieved from https://www.hackster.io/HackingSTEM/hacking-stem-electroconductivity-meter-a82c58

Stream Data from Arduino into Excel. (n.d.). Retrieved from https://create.arduino.cc/projecthub/HackingSTEM/stream-data-from-arduino-into-excel-f1bede

Stream Data from Arduino into Excel. (n.d.). Retrieved from https://create.arduino.cc/projecthub/HackingSTEM/stream-data-from-arduino-into-excel-f1bede

Wendt, Z. (2020, March 6). Solid State vs. Electromechanical Relays. Retrieved from https://www.arrow.com/en/research-and-events/articles/crydom-solid-state-relays-vs-electromechanical-relays