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TELEMETERING FOR KPLC

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DEDICATION

To my ever loving parents, brother and sisters. You have been a great inspiration to me.
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I would like to thank all my classmates, friends, lecturers and all those who have directly and indirectly aided me in the project’s research and execution.

Last but not least, I would like to thank God for giving me the strength, fortitude and ability to carry out this project.
DECLARATION AND CERTIFICATION

This is my original work and has not been presented for a degree award in this or any other university.

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This report has been submitted to the Department of Electrical and Information Engineering, The University of Nairobi with my approval as supervisor:

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ABSTRACT

The power sector in Kenya and generally all over the world has gone through a major restructuring exercise that led to the development of a wholesale electricity market. This strategy resulted in the splitting of the dominant integrated electricity utilities owned by the government into three major entities i.e. Generation, Transmission and Distribution.

The split introduced competition in the Kenyan power sector calling for strict metering and billing for accurate account of energy dispatched, lost or consumed. Therefore, in this information era, the meter coupled with I.T. (information technology) infrastructure and techniques, play a central role in the survival of a power utility. However, KPLC are still metering and billing manually leading to inaccuracy, high operational costs and unnecessary delays.

To avoid such inconveniences, a web based tele metering system is one of the best options to be considered. Given the currently available tele communication infrastructure that includes power line communication, optic fiber and wireless communication like GSM and GPRS, the new system not only goes a long way in shifting the high voltage utilities’ focus from telecommunication and I.T. for power dispatch and control only, but also include metering and billing as one of the priorities. However, it must be emphasized that the success of the system is determined by the reliability and quality of the communication channel.
LIST OF ACRONYMS

AMR Automatic Meter Reading

GPRS General Packet Radio Service

GSM Global System for Mobile Communications

HF High Frequency

HTTP Hyper Text Transfer Protocol

IT Information Technology

Kbps Kilo Bits Per Second

Mbps Mega Bits Per Second

KPLC Kenya Power and Lighting Company

KV Kilo Volt

KVA Kilo Volt-Ampere

KWh Kilo Watt Hour

MW Mega Watts

LAN Local Area Network

OSI Open System Interconnection

PLC Power Line Communication

SCADA Supervisory Control and Data Acquisition

SMS Short Message Service

SOAP Simple Object Access Protocol
SQL Structured Query Language

SSL Secure Socket Layer

UDDI Universal Description Discovery and Integration

KPLC Kenya Power and Lighting Company

UHF Ultra High Frequency

WAN Wide Area Network

WSDL Web Service Description Language

XML Extensible Markup Language
CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION
The current approach of manual metering where KPLC staff move around the country physically reading each meter and delivering data to the headquarters for manual process of billing is subject to human errors, delays, high costs of operation and inaccurate reports.

Proper use of the current telecommunication infrastructure together with proper information technology management in these utilities will help in reducing the shortcomings presented by the manual system.

It is based on this study that critical investigation on the issues surrounding the metering and billing of high voltage power is required. The researcher focused on Kenya Power and Lighting Company as a case study. The main aim of the study was to implement a web based tool to automate metering and billing of high voltage power.

1.2 BACKGROUND TO THE STUDY
Smith (2003) asserts that the electric meter is the cash register of a power utility company. For the consumer of electricity, it is also the source of data to manage consumption and the bill. But getting accurate data to the electric supplier for billing in a timely fashion to the consumer for demand control and reliably managing operations remains a daunting challenge for many. This is attributed to utility companies sticking to manual meter reading and billing with little or no integration of information technology.

Chan et al. (2004) point out that deregulation comes a long with changes in the way electricity is sold which in turn affects the meter reading market. Manual reading of the energy consumption may not be able to cope with such changes. According to Chan, vision inspection of meters is time-consuming and labor-intensive.

Muyingi et al. (2005) advises that telecommunication systems be essential for the core business of any power utility because they provide new opportunities in the deregulated Information and Communication Technology market. High Voltage Power utilities need to make use of this advice by utilizing their telecommunication systems for telemetering.
1.3 DEFINITION OF KEY TERMS

1.3.1 Telemetering:
Telemetering is the process that measures a physical quantity and transfers the value from a remote location to be recorded, displayed, analyzed, or to initiate a control action.

1.3.2 Power:
Energy dissipated in an electrical or electronic circuit or device per unit of time. Electric power is usually measured in Watts, kilowatts (1,000 watts), and megawatts (1,000,000 watts).

1.3.3 Voltage:
The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in volts. High Voltage in this proposal refers to Voltages above 33KV.

1.3.4 Web Based Tool:
A database driven solution designed to run through a browser to link high voltage power meters to remote work stations through a communication channel, download meter readings and thereafter process customer bills.

1.3.5 Global Systems Management (GSM)
This is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile phones. As of 2014 it has become the default global standard for mobile communications

1.3.6 General Packet Radio Service (GPRS)
This is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM). GPRS was originally standardized by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD and i-mode packet-switched cellular technologies. It is now maintained by the 3rd Generation Partnership Project (3GPP).

1.4 PROBLEM STATEMENT
KPLC is charged with distributing power from the generating companies to their respective
customers distributed countrywide. The manual approach to metering and billing has staff moving around physically taking each meter reading and delivering the data to a central location for another manual process of billing. This is prone to human errors, delays, high operational costs and inaccurate reports. This project thus seeks to utilize telecommunication infrastructure to come up with a prototype of a tool which enforces automatic meter reading, timely billing and invoicing of high voltage power utility customers. This is a significant step towards solving problems that are a result of manual operations and also increased use of the otherwise underutilized telecommunication infrastructure in the the country.

1.5 OBJECTIVES

1.5.1 General Objective
The general objective of the project is to develop a remote site telemetering tool for KPLC.

1.5.2 Specific Objectives
- To investigate the metering challenges in high voltage power utilities and the existing telecommunication systems.
- Identify requirements for the design of a web based telemetering system in a high voltage power utility.
- To Design a telemetering system prototype.
- To Implement a telemetering system for efficient metering.
- To test and validate the designed system so as to ensure proper metering power.

1.6 PROJECT SCOPE
Demonstration of a Telemetering tool for KPLC.
1.7 SIGNIFICANCE OF THE STUDY

Figure 1: kplc commercial cycle process

As can be seen from the above KPLC commercial cycle process, a lot of time and resources is wasted while taking meter readings and dispatching bills. Also, without implementation of a web based telemetering tool, customers have to be metered and billed based on a credit (postpaid) metering system which poses the following challenges (as of 2011): [3]
Figure 2: challenges and their annual cost implication

[3]

Therefore, implementation of a web based tool is necessary for the following reasons:

- Loss reduction
- Improvement of customer service
- Decongestion of Banking Halls
- Overcoming commercial cycle challenges
- Enhancing ease of bill payment
- Demand control
CHAPTER 2: LITERATURE REVIEW

1.1 INTRODUCTION
This chapter introduces the components and operation of a Telemetering system necessary for understanding the details of the study.

1.2 ADVANCED METERING INFRASTRUCTURE (AMI)

1.2.1 OVERVIEW OF AMI
Advanced metering systems are comprised of electronic/digital hardware and software, which combine interval data measurement with continuously available remote communications. These systems enable measurement of detailed, time based information and frequent collection and transmission of such information to various parties. AMI typically refers to the full measurement and collection system that includes meters at the customers site, communication networks between the customer and a service provider and data reception and management systems that make information available to the service provider. [1]

1.2.2 AMI COMPONENTS
The customer is equipped with advanced electronic meters that collect time-based data. Meters include all three types—electricity, gas, and water meters. These meters have the ability to transmit the collected data through commonly available fixed networks such as Power Line Communications (PLC), Fixed Radio Frequency (RF) networks, and public networks (e.g., landline, cellular, paging, Wi-Fi). The meter data are received by the AMI host system and sent to the Meter Data Management System (MDMS) that manages data storage and analysis to provide the information in useful form to the utility. AMI enables two-way communications, so communication from the utility to the meter could also take place. [1]
1.3 DATA COLLECTION

The data required to calculate consumer usage is voltage across the lines and current going through the line. Power being used is a product of the two units.

1.4 CURRENT SENSOR

1.4.1 SHUNT RESISTOR

Sensing and controlling current flow is a fundamental requirement in a wide variety of applications including, over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc. One of the simplest techniques of sensing current is to place a small value resistance (also known as Shunt resistor) in between the load and the ground and measure the voltage drop across it, which in fact, is proportional to the current flowing through it. Whereas this technique is easy and straightforward to implement, it may not be very precise because the value of the shunt resistor slightly varies with its
temperature, which in fact is not constant because of the Joule heating. Besides, this simple technique does not provide an isolation between the load and current sensing unit, which is desirable in applications involving high voltage loads.

1.4.2 ALLEGRO ACS712 CURRENT SENSOR.
Allegro ACS712 provides an economical and precise way of sensing AC and DC currents based on Hall-effect.

Figure 4 ACS712-05 current sensor module

The Allegro ACS712 current sensor is based on the principle of Hall-effect, which was discovered by Dr. Edwin Hall in 1879. According to this principle, when a current carrying conductor is placed into a magnetic filed, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field as illustrated in the figure shown below. A thin sheet of semiconductor material (called Hall element) is carrying a current (I) and is placed into a magnetic field (B) which is perpendicular to the direction of current flow. Due to the presence of Lorentz force, the distribution of current is no more uniform across the Hall element and therefore a potential difference is created across its edges perpendicular to the directions of both the current and the field. This voltage is known Hall voltage and its typical value is in the order of few microvolts. The Hall voltage is directly proportional to the magnitudes of I and B. So if one of them (I and B) is known, then the observed Hall voltage can be used to estimate the other. [6]
The ACS712 device is provided in a small, surface mount SOIC8 package. It consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. When current is applied through the copper conductor, a magnetic field is generated which is sensed by the built-in Hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conduction path, providing a linear relationship between the output Hall voltage and input conduction current. The on-chip signal conditioner and filter circuit stabilizes and enhances the induced Hall voltage to an appropriate level so that it could be measured through an ADC channel of a microcontroller. The pin diagram of ACS712 device and its typical application circuit is shown below. Pins 1, 2 and 3, 4 forms the copper conduction path which is used for current sensing. The internal resistance of this path is around 1.2 milliohms, thus providing low power loss. As the terminals of this conduction path are electrically isolated from the sensor leads (pins 5 through 8), the ACS712 device eliminates the risk of damaging the current monitoring circuit due to the high voltage on the conduction side. The electrical isolation between the conduction current and the sensor circuit also minimizes the safety concerns while dealing with high voltage systems. [6]
In low-frequency applications, it is often desirable to add a simple RC filter circuit at the output of the device to improve the signal-to-noise ratio. The ACS712 contains an internal resistor (RF) connected between the the output of the on-chip signal amplifier and the input of the output buffer stage (shown below). The other end of the resistor is externally accessible through pin 6 (Filter). With this architecture, users can implement a simple RC filter through the addition of an external capacitor (CF) between the Filter pin and ground. It should be noted that the use of external capacitor increases the rise time of the sensor output, and therefore, sets the bandwidth of the input signal. The maximum bandwidth of the input signal is 80 KHz at zero external filter capacitor. The bandwidth decreases with increasing CF. The datasheet of ACS712 recommends to use 1 nF for CF to reduce noise under nominal conditions. [6]

Figure 7 Functional block diagram of ACS712

1.4.3 Sensitivity and output of ACS712

The output of the device has positive slope when an increasing current flows through the copper conduction path (from pins 1 and 2, to pins 3 and 4). The ACS712 device comes in three variants, providing current range of ±5A (ACS712-05B), ±20A (ACS712-20B), and ±30A (ACS712-30A). The ACS712-05B can measure current up to ±5A and provides output sensitivity of 185mV/A (at +5V power supply), which means for every 1A increase in the current through the conduction terminals in positive direction, the output voltage also rises by 185 mV. The sensitivities of 20A and 30A versions are 100 mV/A and 66 mV/A, respectively. At zero current, the output voltage is half of the supply voltage (Vcc/2). It should be noted that the ACS712 provides ratiometric output, which means the zero current output and the device sensitivity are both proportional to the supply voltage, VCC. This feature is particularly useful
when using the ACS712 with an analog-to-digital converter. The precision of any A/D conversion depends upon the stability of the reference voltage used in the ADC operation. In most microcontroller circuits, the reference voltage for A/D conversion is the supply voltage itself. So, if the supply voltage is not stable, the ADC measurements may not be precise and accurate. However, if the reference voltage of ADC is same as the supply voltage of ACS712, then the ratio metric output of ACS712 will compensate for any error in the A/D conversion due to the fluctuation in the reference voltage. Any fluctuation in the reference voltage will not be a source of error in the analog-to-digital conversion of the ACS712 output signals. The curve below shows the nominal sensitivity and transfer characteristics of the ACS712-05B sensor powered with a 5.0V supply. The drift in the output is minimum for a varying operating temperature, which is attributed to an innovative chopper stabilization technique implemented on the chip. [6]

![Output Voltage versus Sensed Current](image_url)  
Figure 8 Output voltage vs sensed current of ACS712-05B at 5.0 V power supply and varying temperature

1.5 COMMUNICATIONS NETWORK

1.5.1 GSM MODEM

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet
connectivity, many of them can also be used for sending and receiving SMS and MMS messages. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it can be a mobile phone that provides GSM modem capabilities. The term GSM modem is used as a generic term to refer to any modem that supports one or more of the protocols in the GSM evolutionary family, including the 2.5G technologies GPRS and EDGE, as well as the 3G technologies WCDMA, UMTS, HSDPA and HSUPA. A GSM modem exposes an interface that allows applications to send and receive messages over the modem interface. The mobile operator charges for this message sending and receiving as if it was performed directly on a mobile phone. To perform these tasks, a GSM modem must support an “extended AT command set” for sending/receiving SMS messages. [4]

GSM modems can be a quick and efficient way to get started with SMS, because a special subscription to an SMS service provider is not required. In most parts of the world, GSM modems are a cost effective solution for receiving SMS messages, because the sender is paying for the message delivery. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection. The serial port allows for interface with the microcontroller unit and programmed to send required information remotely. [4]

1.6 MICROCONTROLLERS

1.6.1 Definition

A microcontroller is a programmable digital processor with necessary peripherals on chip.

1.6.2 Basic structure of a microcontroller

A typical micro-controller has functional blocks that carry out the functions below: [3]

a) The C.P.U. is the central processing unit. The C.P.U. scrutinizes and manages all processes that are carried out in the micro-controller. This is done by interpreting and
carrying out the programs stored in the R.O.M. It consists of several smaller subunits the most important being:

I. Instruction decoder which recognizes program instructions and runs the other circuit based on the instructions. The capabilities of this circuit are expressed in the ‘instruction set’ which is different for different micro-controller families.

II. Arithmetical logical unit (ALU) which performs all mathematical and logical operations on data.

III. Accumulator is a special function register used for storing all data upon which some operations should be executed. It also stores results for which further processing is required.

b) Interrupt control which handles interrupts. An interrupt is a sub-routine call that changes the sequence of execution of the micro-controller programs so that the micro-controller can perform some other program which is extra important at the time.

c) The Read Only Memory (R.O.M) stores a set of commands known as a program. This program instructs the micro-controller to perform specific tasks.

d) The Random Access Memory (R.A.M.) is a storage space which momentarily stores data during the execution of a program.

e) A bus is a group of wires carrying information with a common purpose. There are three types of buses: Address bus which carries the address of a specific location, data bus which carries information between the C.P.U. and memory or I/O devices and control bus which carries the control signals from the C.P.U. to synchronise the movement of information on the address and data bus. I/O ports enable us to connect the micro-controller to peripheral devices.

f) The oscillator generates even pulses which enable harmonic and synchronous operation of all circuits within the micro-controller.

g) Timers/counters: These are special function registers which are automatically incremented during the execution of a program.
1.6.3 Classification of microcontrollers

There are millions of microcontrollers that have been manufactured to date. This makes it very difficult to explicitly classify them as many of them are made specific to a given application. Nevertheless, when one is designing a system that incorporates a microcontroller the main considerations one has to consider are:

1.6.4 Hardware architecture

Hardware architecture is how the various components in the microcontroller relate with each other. There are two main architectural categories which differ in the way data and programs are accessed. They are:

a) Von-Neumann/Princeton architecture [4]

Microcontrollers based on this architecture have a single bus for fetching instructions and data. Program instructions and data are stored in a common main memory. If the microcontroller wants to process data stored in the memory, it first fetches the instruction, and then it fetches the data to support the instruction. Thus for a single operation we need at least two fetches which slows up the microcontroller’s operation. The main advantage of this architecture is that it simplifies the microcontroller design because only one memory is needed. An example of a microcontroller that uses the von Neumann architecture is the Motorola 68hc11.

b) Harvard architecture [4]

In the Harvard architecture, the microcontroller’s instruction bus is separate from the data bus. Program instructions and data are also stored on different memory spaces. With this architecture as the next instruction is being fetched, the current instruction is being executed. This leads to a much faster execution as compared with the Princeton architecture but this is achieved at the expense of hardware complexity. Most microcontrollers available in the market use the Harvard architecture. Examples of microcontrollers using the Harvard architecture are the PIC microcontrollers.
1.6.5 **Instruction bus width**

Here the microcontrollers are divided depending on whether the ALU performs arithmetic and logical operations on a nibble, byte, word or double-word per instruction. If the operation is on a nibble then the microcontroller is a 4-bit microcontroller. If the operation is on a byte then the microcontroller is an 8-bit microcontroller, if it’s on a word then it is a 16-bit microcontroller and if it’s on a double-word then it’s a 32-bit microcontroller. The computing power increases with the more n-bits that one can process thus making the 32-bit microcontroller the most powerful in terms of computing performance and the 4-bit microcontroller the least powerful.

1.6.6 **Instruction set architecture**

Instructions are specific commands ordered which if executed in a specific order carry out a desired task. All commands available for a given microcontroller are known as an instruction set. Instruction set architecture is the interface that allows for easy communication between software and hardware. The performance of any architecture can be evaluated using the formula: Time/program = instructions/program * cycles/instruction * time/cycle.

There are two main types of instruction set architecture:

a) **Complex instruction set computer (C.I.S.C.)** [4] In CISC architecture the instruction set is large and easy to use. The CISC architecture increases performance by reducing the number of overall instructions. This is done using a microcode that handles complex instructions and tells the processor what to do with them. The instructions in CISC require many clock cycles to implement a single instruction.

b) **Reduced instruction set computer (R.I.S.C.)** [4] RISC architecture has a small but efficient instruction set. It doesn’t have a micro code engine. RISC architecture uses less complex instructions over multiple times to carry out a program. Every instruction takes one clock cycle to implement.

1.6.7 **Included Features**

Important features include an inbuilt ADC that is very important in applications where we need to convert data from analog to digital format, built-in program flash memory which is important if we need to rewrite the program in the microcontroller, facility to interface with external memory, timers especially a watchdog timer and the available interrupts.
1.6.8 Application of microcontrollers

Some of the well-known microcontroller applications include the following:

- Robotics
- Aerospace
- Automobiles (climate control, diagnostics, engine control)
- Environmental control (greenhouse, factory)
- Appliances (television, stereos, microwave oven and refrigerators)
- Instrumentation

1.6.9 ARDUINO UNO

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.
1.6.9.1 TECHNICAL SPECIFICATIONS

Microcontroller: ATmega328

Operating Voltage: 5V

Input Voltage (recommended): 7-12V

Input Voltage (limits): 6-20V

Digital I/O Pins: 14 (of which 6 provide PWM output)

Analog Input Pins: 6

DC Current per I/O Pin: 40 mA

DC Current for 3.3V Pin: 50 mA

Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

1.6.9.2 POWER

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- VIN - The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V** - The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3.3V** - A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND** - Ground pins.

1.6.9.3 MEMORY
The Atmega328 has 32 KB of flash memory for storing code (of which 0.5 KB is used for the bootloader); It has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library). [7]

1.6.9.4 INPUT AND OUTPUT
Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:
- **Serial:** 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts:** 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM:** 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- **SPI:** 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
• LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

• I 2C: 4 (SDA) and 5 (SCL). Support I2C (TWI) communication using the Wire library. There are a couple of other pins on the board:
  • AREF. Reference voltage for the analog inputs. Used with analogReference().
  • Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board. [7]

1.6.9.5 COMMUNICATION

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required.

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-toserial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. [7]
1.6.9.6 AUTOMATIC (SOFTWARE) RESET

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data. [7]

1.6.9.7 USB OVERCURRENT PROTECTION

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed. [7]
1.1 INTRODUCTION
This chapter gives an overview of how the simulation is set up and a breakdown of the logic behind the different components used and their functions.

The proposed system implementation is based on an Arduino microcontroller unit that directly interfaces with the GSM modem. Power consumed is calculated by monitoring voltage, current and power factor on the line as required by the formula;

\[ \text{POWER} = \text{LINE VOLTAGE} \times \text{LINE CURRENT} \]

Current is measured by use of current sensor which monitors the current on the line. The microcontroller unit reads the number of units calculated and sends the data to the GSM modem. The GSM modem sends the meter reading of the consumer to the service provider who maintains a database of all the customers power consumption and to the customer via Short Messaging Service (SMS). The readings are fed automatically with the help of wireless transmission. The LCD connected to the microcontroller shows the meter reading of consumption as measured by the energy meter. Such metering unit is also known as a ‘Smart Meter’. [5]

A block diagram of the system is shown figure 9;
The working module of the smart meter is shown on the flow chart below: where current and voltage sensors are used to calculate the meter reading and values stored in the microcontroller unit. Received values are fed to the GSM modem, displayed on the LCD and sent to the user’s phone via SMS [5]. Power to the consumer can also be isolated using relays. This is especially useful in the case of unpaid bills.
1.2 CURRENT MEASUREMENT.
In order to calculate power, current is a requirement. This current is measured using a Hall Effect Current Sensor that provides isolation with the load circuit.
1.2.1 USING ACS712 30A HALL EFFECT SENSOR.

The ACS712 is an integrated system from Allegro Microsystems. It allows measurement of direct and alternating current flowing in a conductor to up to 30A. The measured current generates a magnetic field which is converted by the sensor to a proportional output voltage using the Hall Effect. The voltage is input into an analog pin of the Arduino microcontroller and the signal is converted to digital. AC current is in most cases expressed in RMS. In order for the ACS712 current sensor to be used to measure AC current, RMS current value should be calculated from the device readings.

![Current Waveform Diagram]

Volts RMS is given by the equation;

\[ VOLTS RMS = VOLTS PEAK \times 0.707 \]

In ACS712 current sensor, current measurements are reported with a voltage output. Thus RMS volts is calculated and a scale factor applied.

Conversion for the sine wave with a zero volt offset is performed as follows:

1. Finding peak to peak volts
2. Dividing peak to peak voltage by two to get peak voltage (volts peak).
3. Multiplying the peak voltage by 0.707 to get RMS volts (volts RMS).
With RMS voltage calculated, it is multiplied by the scale factor of ACS712 to yield the RMS value of current being measured.

The output values from the ACS712 are constantly changing when measuring AC current. To make sure that the peaks are measured as closely as possible, the values need to be sampled fast and long enough. Since the mains power is at 50 - 60 Hz, the Arduino is fast enough provided it takes consecutive samples with little or no interruption.

In the code, the ‘getVPP’ function is called from the main loop in the function. AC samples are taken for one second while recording the maximum and minimum values. From this, peak to peak voltage is calculated.
1.2.1.1 Circuit diagram for measuring current

![Circuit Diagram for Measuring Current](image1.png)

Figure 12: Circuit diagram for measuring current

1.2.1.2 ARDUINO CODE FOR CURRENT MEASUREMENT

Since the Arduino takes raw values of current in terms of voltage in analogpin0 and converted to digital values, necessary conversions in the values obtained is required so as to have correct current readings.

A code was written, compiled and run for Arduino to do all the necessary calculations and obtain the RMS value of current.

The value of current is displayed on the LCD display and is also used in calculation of power.
1.3 VOLTAGE MEASUREMENT

1.3.1 VOLTAGE SENSOR

To measure the mains AC voltage, the voltage needs to be stepped down. Since microcontrollers can’t measure voltage greater than 5V, as the analog pins may get damaged permanently, the mains voltage has to be stepped down to AC voltage whose peak value should be less than 5V. A voltage transformer is used for stepping down the voltage.

To also make the measurement easy to read, the voltage is converted to DC voltage and further stepped down using resistors as voltage dividers. A code is written to relate the DC output voltage of the voltage sensor circuit to input of the transformer which is the mains voltage. The sensor value is input to AnalogPin1 of the Arduino.

The output of the transformer at 6V AC, a full bridge rectifier is used to convert the AC voltage to DC, a value easily readable by the microcontroller unit. A 330μF capacitor is used to smoothen the DC voltage. Output at this stage is 10V DC. This value isn’t readable through the analog pins of the microcontroller unit thus needs to be stepped down to below 5V. A voltage divider is introduced into the circuit. Its made up of two resistors; 2.2K and 1K.

Theoretical calculations based on 240V mains voltage is as follows:

\[ 10V \times \frac{1K}{1K+2.2K} = 3.125V \text{ (equivalent to 240V mains voltage)} \]

Thus Step Down Factor \( \frac{240V}{3.125V} = 76.8 \)

Since 5V digital sensor value equivalent is 1023, conversion factor from sensor values is given by:

\[ \frac{1023}{5} = 204.6 \]

Thus to convert sensor values to mains voltage, the following relation is used:
$VOLTAGE = \frac{SENSOR\ VALUE}{204.6} \times 76.8$

Figure 13: voltage sensor

1.4 CALCULATING ENERGY USED

With voltage and current obtained, value of energy used is calculated as:

$ENERGY = VOLTAGE \times CURRENT$

In domestic case Power Factor is ignored and its calculation isn’t necessary.

1.5 SAVING ENERGY READINGS IN CASE OF DAMAGE TO MICROCONTROLLER UNIT

The energy readings taken by the microcontroller unit needs to be saved in the case of power outage or disconnection. If not saved the data containing energy readings will be lost and the
information sent to consumer and distribution company will only reflect energy consumed after replacement. This is not good especially for billing.

The data is saved constantly in an SD card and retrieved in the case of system failure. SD card module is used to interface the Arduino and the SD card as shown below.

![Figure 14: interfacing SD card module with Arduino](image)

The following code is used to write and read the SD card:

```c
1.6 SENDING ENERGY READINGS VIA GSM MODULE
The energy readings are forwarded to the consumer’s mobile phone using the GSM module. The module used is SIM800. The code used is as shown below.
```
CHAPTER 4: RESULTS

The telemetering gadget was successfully built but for some minor issues related to sending to and reading from the remote location.

Figure 15: image of final project
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Figure 16: voltage, current and energy measurement results using light load as seen in the serial port

1.6.1 WEB INTERFACE

Data can also be accessed via a web interface as shown in Figure 17, 18 and 19.
Figure 17: HOME PAGE

Figure 18: ABOUT PAGE
Figure 19: CONTACT PAGE
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

1.1 CONCLUSION
The main objective of the project was to develop a Telemetering tool that measures transmits the data via a G.S.M. network to a website where it can be viewed remotely. The web interface wasn’t successful though it was a success to send via SMS. Voltage and current sensors worked well and produced accurate readings.

Objectives of the project were partially achieved.

1.2 RECOMMENDATIONS FOR FUTURE WORK
The recommendations for future work are as follows:

- Developing a means of modifying the G.P.R.S. bearer settings in the microcontroller program such that a user won’t be restricted to using the Airtel network.
- Investigate how to protect the data collected by making sure users only get to access only those devices that they are authorized to.
- Developing a means of further processing the data that has been posted. Such processing can include plotting of graphs and converting the data into a format easily transferrable to another website or to other programs such as spreadsheets.
REFERENCES

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4. GSM MODEMS- Now Wireless Limited Bourne House, 475 God stone Road, Whyteleafe, CR3 0BL, UK


6. Fully Integrated, Hall Effect-Based Linear Current Sensor IC with 2.1 kVRMS Isolation and a Low-Resistance Current Conductor

7. A Complete Beginners Guide to the Arduino - By Mike McRoberts
APPENDIX

MEASURING AC CURRENT USING ACS712 CODE

// include the library code:
#include <LiquidCrystal.h>

const int sensorIn = A0; // define input pins

int mVperAmp = 66; // sensitivity 66mV/Amp

double Voltage = 0; // initialize voltage

double VRMS = 0;

double Irms = 0;

void setup(){
    Serial.begin(9600);
}

void loop(){
    Voltage = getVPP(); // obtain peak to peak voltage of signal from current sensor
    VRMS = (Voltage/2.0) * 0.707; // calculation to get VRMS proportional to current
    Irms = (VRMS * 1000)/mVperAmp; // conversion of rms signal from current sensor to rms current
    Serial.print(Irms);
    Serial.println(" Amps RMS");
}

lcd.print(Irms);

lcd.print(" A RMS"); // print to lcd
float getVPP()
{
    float result;
    int readValue; // value read from the sensor
    int maxValue = 0; // store max value here
    int minValue = 1024; // store min value here
    uint32_t start_time = millis();

    while((millis() - start_time) < 1000) // sample for 1 Sec
    {
        readValue = analogRead(sensorIn); // see if you have a new maxValue
        if (readValue > maxValue)
        {
            /* record the maximum sensor value */
            maxValue = readValue;
        }
        if (readValue < minValue)
        {
            /* record the maximum sensor value */
            minValue = readValue;
        }
    } // Subtract min from max

    result = ((maxValue - minValue) * 5.0) / 1024.0;
    return result;
}
#include <LiquidCrystal.h>

#define sample_no 10

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

const int sensorIn1 = A4; // voltage sensor input at analogpin1

int sensorValue1 = 1;

double Voltage = 0;

void setup() {
    // put your setup code here, to run once:
    lcd.begin(20,4);
    Serial.begin(9600);
}

void loop() {
    sensorValue1 = analogRead(sensorIn1);
    Voltage = sensorValue1*0.00488758533*80; //DIVIDE BY 1/204.6
    lcd.print(Voltage);
    lcd.print("V");
    delay (1000);
}
include File myfile;

void setup() {
  Serial.begin(9600);
  Serial.println("Initializing card...");
  // declare default CS pin as OUTPUT
  pinMode(10, OUTPUT);
  if (!SD.begin(4)) {
    Serial.println("initialization of the SD card failed!");
    return;
  }
  Serial.println("initialization of the SDcard is done.");
  myfile = SD.open("textFile.txt", FILE_WRITE);
  if (myfile) {
    Serial.print("Writing to the text file...");
    myfile.println(Energy);
    myfile.close(); // close the file:
    Serial.println("done closing.");
  } else {
    // if the file didn't open, report an error:
    Serial.println("error opening the text file!");
  }
  // re-open the text file for reading:
  myfile = SD.open("textFile.txt");
  if (myfile) {
    Serial.println("textFile.");
    // read all the text written on the file
    while (myfile.available()){
      Serial.write(myfile.read());
    }
  }
}
// close the file:
myfile.close();
}
else {
    // if the file didn't open, report an error:
    Serial.println("error opening the text file!");
}

void loop() {}
void SIM900power()

// software equivalent of pressing the GSM shield "power" button
{

digitalWrite(9, HIGH);
delay(1000);
digitalWrite(9, LOW);
delay(7000);
}

void sendSMS(String message)
{

SIM900.print("AT+CMGF=1\r"); // AT command to send SMS message
delay(100);

SIM900.println("AT + CMGS = "+254735596232\r"); // recipient's mobile number, in international format
delay(100);

SIM900.println(message); // message to send
delay(100);

SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26
delay(100);

SIM900.println();
delay(5000); // give module time to send SMS
SIM900power(); // turn off module
void loop()
{
    x = random(0,255);
    y = random(0,255);
    textForSMS = Irms;
    textForSMS.concat(x);
    textForSMS = textForSMS + volts;
    textForSMS.concat(y);
    textForSMS = textForSMS + energy;
    sendSMS(textForSMS);
    do {} while (1);
}