Smart Metering Using Powerline Communication

Rizwan Iqbal[1], Nadia Mustaqim Ansari[2], Huzair Khan[1], Izaan Ali[1], Adnan Waqar[2], Sohail Rana[2], Arsalan Ullah Khan[1], Muhammad Noman[1] and Maqsood ur Rehman Awan[2]

[1]Department of Telecommunication Engineering, Dawood University of Engineering & Technology, Karachi, Pakistan

[2]Department of Electronic Engineering, Dawood University of Engineering & Technology, Karachi, Pakistan

Corresponding author: Rizwan Iqbal (rizwan.iqbal@duet.edu.pk).

Abstract- Electricity plays a vital role in the economic growth of the country. In Pakistan, electric suppliers and consumers suffer because of pitfalls that may include human errors in billing, security breaches, and electricity theft. Smart metering systems hold the key to solving these issues. Unlike traditional metering systems, it benefits both vendor and consumer by displaying real-time data about electrical usage. There are many approaches found to be quite expensive. Power line communications offer an economical solution. It makes use of existing powerlines to transmit electricity. These transmission lines share data and power with low-frequency signals, generally at 50-60 Hz. The proposed system consists of three sub-sections; the vendor, consumer, and PLC MODEM, which act as a mediator to drive data and power. PLX-DAQ is used to display the serial data on a workstation. This method proved to be the most economical since no additional hardware is required, there is no licensing, minimal losses, high availability of resources, and a high data rate. In future enhancement, different options to achieve ubiquity. It is possible to deploy this system over a public cloud to keep track of energy consumed by appliances. In a nutshell, we can say that this method will set a benchmark as one of the most effective and inexpensive methods.

Index Terms- Smart Energy Meter (SEM), Automatic Meter Reading (AMR), Smart Metering System (SMS), Power-Line Communication (PLC), Virtual Terminal (VT).

I. Introduction

The smart energy meter is a simple framework that allows organizations to record readings, display them in real time, and determine billings without visiting the customer's premises [1]. This implementation will improve the previously deployed traditional metering systems, including both wireless and wired approaches Human errors in manual reading, electricity theft, and meter manipulation are some of the critical issues connected with outdated metering systems that this technology may be able to solve. This approach is based on AMR, which stands for Automatic Meter Reading (AMR) is a well-designed approach to tackle the significant problems of electricity theft [2]. It provides a strong foundation for intelligent metering technologies. AMR proved to be very constructive in reducing the work from the regulatory[3]. In this technology, the human effort will likewise be removed [4]. Human error can be remedied because of this elimination. It will also aid in the prevention of corruption, whether perpetrated by customers or employees [5]. It will have a positive impact on revenue collection. The goal is to achieve bidirectional communication between the customer and vendor by serially transmitting data over existing transmission lines without human intervention [6]. The system comprises the powerline communication module; we utilized narrowband PLC module KQ330-FSK, which provides a connection to the main transmission line (generally 220 v at 50-60 Hz) at one end while the other end is connected to the meter carrying the load at consumer section, at vendor section another PLC module is set up to interconnect the consumer with the vendor using primary power medium [7]. The microcontroller and LCD are also connected at both ends to carry out serial communication and real-time display about the electricity usage [8].

II. Problems in Metering Systems

- Conventional billing systems are expensive and inaccurate.
- The existing billing system may require an agent to record readings and transmit them to the authority physically. However, this method is erroneous and time-consuming.
- As further, the current billing system is based on digital meters, which are slow at measuring electricity.
- Other smart approaches required highly skilled staff, additional management antenna adjustments, licensing issues, and fragility to external environmental conditions.

III. Methodology

As shown in figure 1, the system is divided into two sections 1 is the consumer side, where the meter is placed with an isolation circuit, i.e., optocouplers record the power consumed by loads connected, the OP-AMP acts as voltage and current square wave generator for XOR. Similarly, the output of the XOR gate acts as input to the microcontroller to measure the readings. The actual measurement of tasks is carried out in the consumer section. The PLC MODEM connected at both ends use to couple or separate the data with a power signal (50Hz 220 VAC). The vendor section receives and displays the data using an LCD connected to Arduino UNO. Further, this data is transferred serially to the workstation with installed data acquisition software to display the data in spreadsheet format.

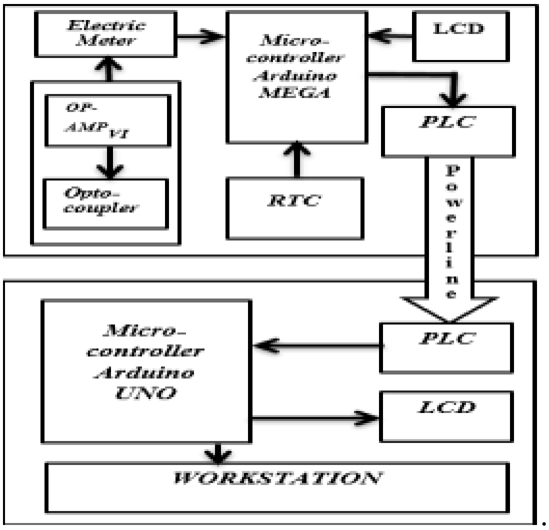

FIGURE 1. **Block diagram**

TABLE I
HARDWARE AND SOFTWARE SPECIFICATIONS

Item	Description
OS	WINDOWS 10
interface	UART, COM
input	voltage current
power consumption	kilowatt, KVAR
frequency	50 Hz
baud rate	9600 bauds
modulation	FSK
PLC modem	KQ330-FSK
bandwidth	120KHz
speed	10kbps approximately
diodes	IN4007, IN733A
optocoupler	4N35
OP-AMPs	LM358
XOR gate	XOR
RTC	DS3232
LCD	VT
resistors	1K,4K,10K,220ohm
capacitors	1uF
current sensor	ACST-12
load	any appliance support $220V_{AC}$
PLX-DAQ	data acquisition tool

A. HARDWARE SPECIFICATION

1) DIODE (IN4007):

1N4007 is a PN junction rectifier diode. These diodes allow only the flow of electrical current in one direction. So, it can be used to convert AC power to DC [9]. 1N 4007 is electrically compatible with other rectifier diodes and can be used instead of any diodes belonging to the 1N400X series.

2) ZENER DIODE (IN733A):

The semiconductor that allows current to flow in either forward or reverse bias. In forward biased, the current flows in the forward direction [10]. In reverse narrow, when the reverse current exceeds the threshold level, the diode enters the Zener breakdown or avalanche zone [11]. The main functionality of this diode in the proposed system is to prevent the microcontroller from being damaged by isolating the high voltage levels (above 5V).

3) OPTO-COUPLERS (4N35):

OPTO-couplers are used for isolation and switching purposes since it is not necessary but efficient to prevent high voltage spikes in the case of high-power transmissions [3].

4) CURRENT SENSOR (ACST-12):

The current sensor is used for load detection since the input of the current detector is connected to the load, which is some electric motors, and the output of the current sensors is directly related to the information of the operational amplifier to generate square waves for current [12].

5) DS3232:

DS3232 is used for real-time operations. It`s a counter that counts the time or keeps track of time-dependent functions, e. g to generate power values per second [13].

6) CAPACITORS:

In this system, the function of the capacitor is to keep the voltage at a defined and precise level [14].

7) RESISTORS:

Resistors in this system have multipurpose. Other than the general purpose of the resistor is to control the flow of electric current and serves as a divider circuit, dividing 12 volts into 3.3 to 5 volts [15].

8) XOR:

XOR is a bitwise operator that returns 0 logic at the output if the input values are the same (1, 1/0, 0) or one logic at work [16].

9) MOTORS:

Electric motors are nothing but used as a load; alternatively, we can use other appliances. The output of electric motors is connected to the input of the current sensor to estimate the current usage [17].

10) ARDUINO UNO:

Arduino is an open-source platform used for electronic projects. It has some advantages over other controller boards

- Consist of physical boards.
- Community support.
- Easy programming language than C or C++.
- No additional hardware required.

Arduino boards consist of memory (RAM, ROM), Analog, and digital pins require to run the system [18].

B. PROPOSED METHOD

Our proposed circuit estimates the real-time readings and displays these data, i.e., voltage, current, power factor, phase, frequency, apparent power, and actual power, onto a serial monitor further; these data values can be delivered serially to the FSK-KQ-330 module the which is modulated and injected to the powerlines carrying 220 VAC at 50 Hz, at receiving side these are another FSK –KQ330 module placed that gets the data and demodulates the data and proceed this data to the microcontroller where microcontroller displays the LCD information and delivered serially over PC [19]. To display this serially produced data, it is necessary to use some sort of application that transforms the data into a proper sequence. Therefore, we will use PLX-DAQ, a data acquisition tool for the microcontroller that converts the data into a spreadsheet program.

C. SYSTEM DESIGN

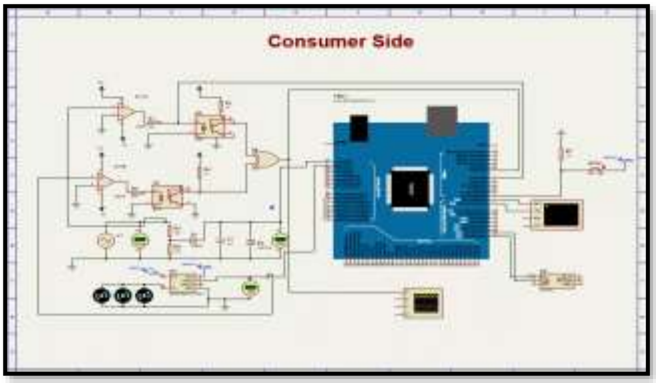

FIGURE 2. **Simulation Design (Consumer Side)**

To generate isolated square waves and convey data as digital pulses with an attached XOR gate, it comprises OP-AMPs and an optocoupler, as shown in figure 2. While electrical loads, such as motors, are linked with voltmeters and current sensors to record voltage and current values. A voltage divider breaks down the 220Vac power source's voltage to 5V, the microcontroller's supported voltage range. RTC controls the process [20].

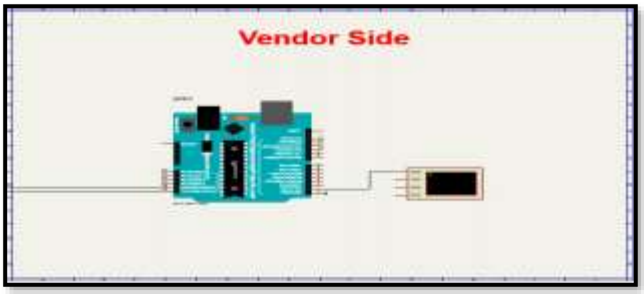

FIGURE 3. **Developed Model (Vendor Side)**

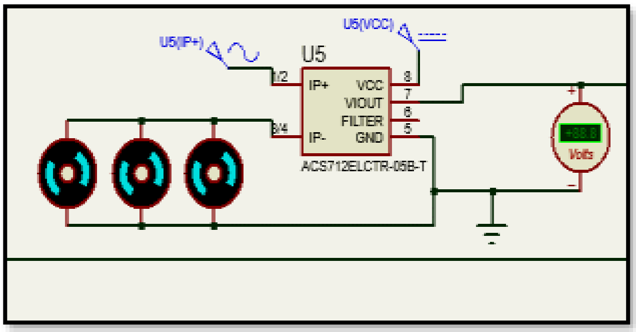

FIGURE 4. **Current Measuring Unit**

It consists of an ACS712 current sensor connected to the primary voltage source. It senses the current drawn by load and outputs this to the analog (A1) of Arduino Uno [21].

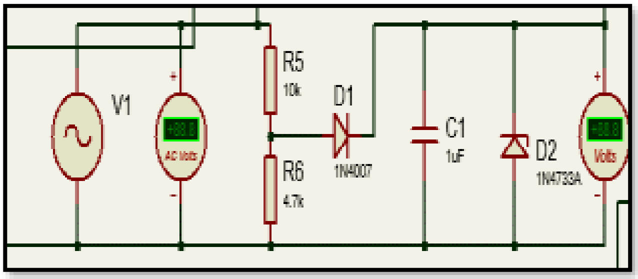

FIGURE 5. **Voltage Measuring Unit**

Figure 5 shows that 220 V_{ac} 50 Hz supply voltage source with voltage divider circuit to breakdown voltage about 5v to be fed into microcontroller [22].

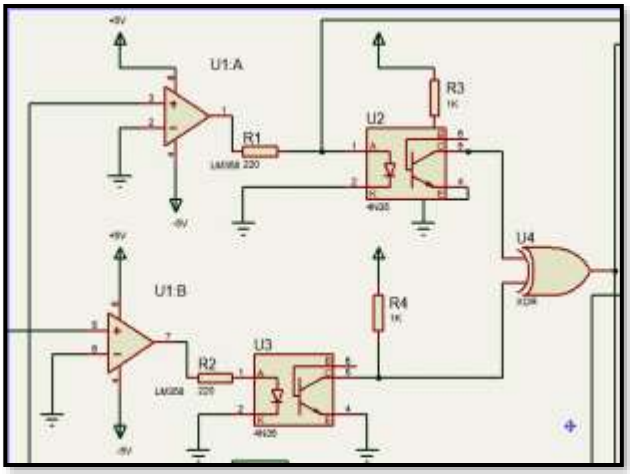

FIGURE 6. **Optocoupler comparator circuit**

Figure 6 shows that both op-amps carry voltage and current input with an optocoupler to generate isolated square waves. Further, this data can be fed into the PWM pin of the microcontroller using the XOR gate [23]. XOR gate acts as a mediator between the optocoupler arrangement and the microcontroller, which compares the output from the optocouplers and generates the differential output [24].

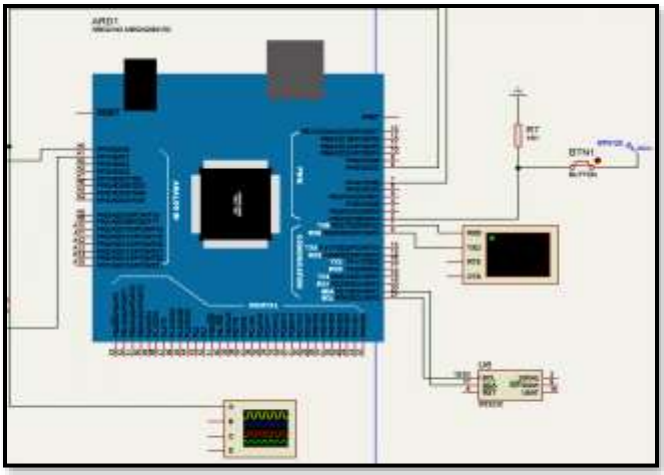

FIGURE 7. Microcontroller Unit

It consists of Arduino UNO connected with RTC (real-time clock) by (SDA) Serial data pin and (SCL) Serial clock pic to provide real-time reading which is displayed on the virtual terminal and to display the PWM signal oscilloscope is used which is connected to the microcontroller by (Pin 8) shown in figure 7.

IV. Result

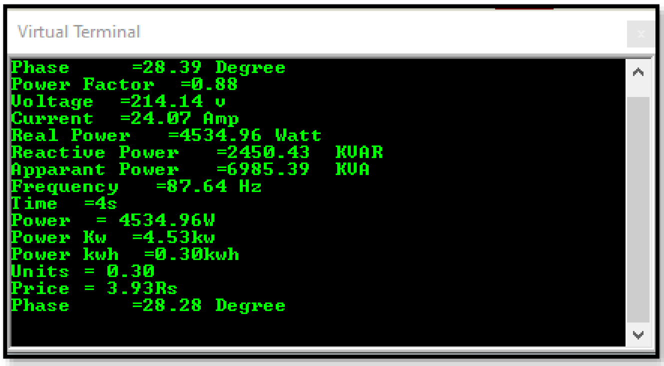

FIGURE 8. Results of Overall Parameters

In figure 8 the Virtual Terminal displays the following parameters as a result:

Voltage: Normally 220V as per vendor policies.

Current: consumed by loads connected.

Power-Factor: the ratio between actual and apparent power, or it can be said that it`s a phase difference between voltage and current. In an efficient power grid system, the power factor must be nearly equal to or less than 1.

Apparent Power: Maximum power that a grid system can handle or withstand. It's a combination of reactive power and actual power.

Actual Power: The power consumed by loads connected is called real power.

Reactive Power: The reactive power is the remaining power that represents the energy stored in a coil that proceeds back to the grids

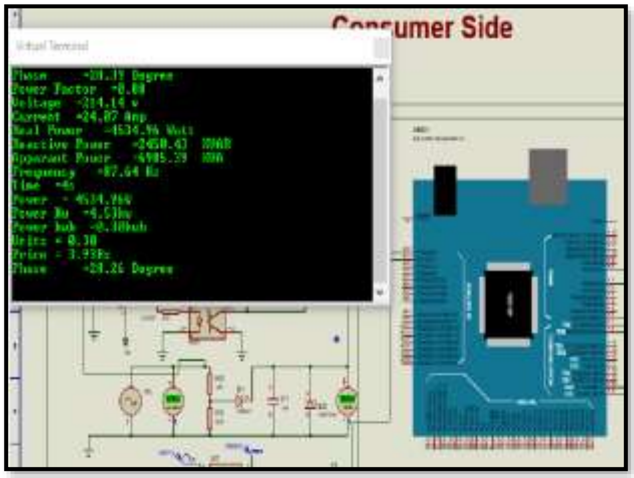

FIGURE 9. Results of Consumer Section

Figure 9 displays the consumer section at which estimation of parameters (voltage, current, power factor, real power, apparent power, price, etc.) is carried out; for this purpose, the microcontroller acts as a core component in the calculation of power factor. Power factor is calculated by measuring the difference between voltage and current pulses incoming from OP-AMPS. For this purpose, X the OR gate is used to the sea and high signal if both voltage and current pulse differ and deliver it to PWM pin the of the microcontroller. Further estimation is done by the code burned in the microcontroller.

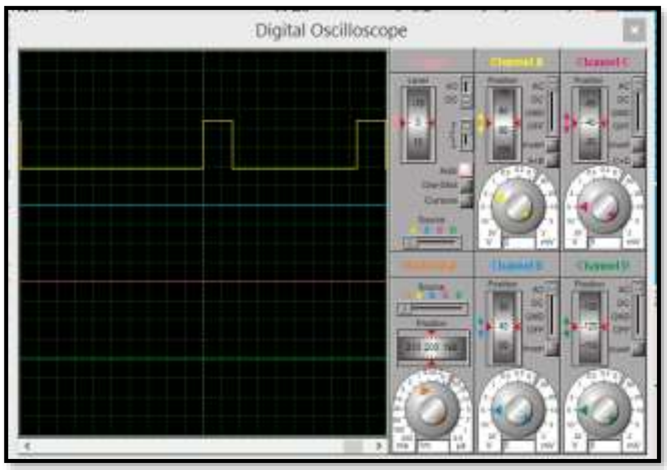

FIGURE 10. Pulse Width Modulation

Yellow pulse displays, the PWM pulse carries out data values (voltage, current) to be estimated via a microcontroller.

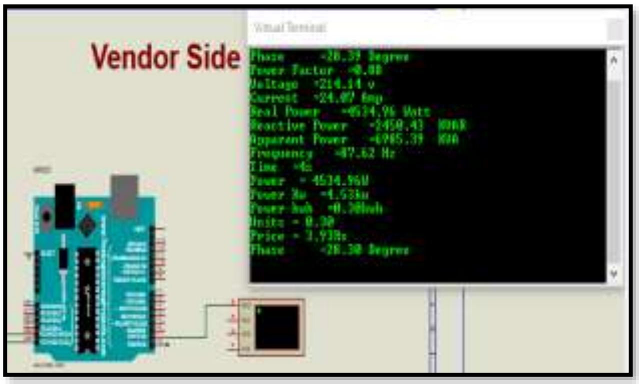

FIGURE 11. **Results of Vendor Section**

The vendor section is in charge of obtaining and visualizing the data in the correct format. For this purpose, a microcontroller is programmed to display the data received from a PLC modem over an LCD connected to the microcontroller. As shown in figure 11.

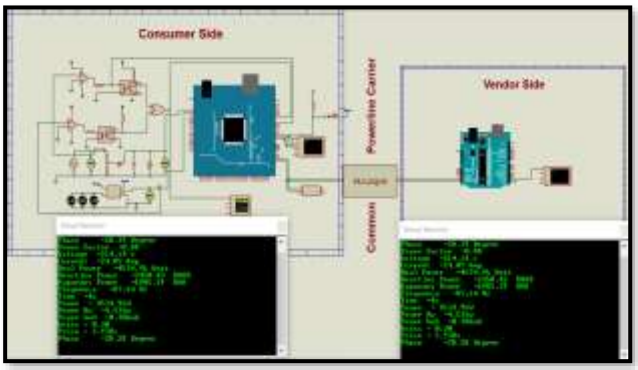

FIGURE 12. **Developed Model Results**

To ensure reliable data transfer, it is necessary to match the data transferred from one end and the data received at the other. Similarly, figure 12 shows the results of both consumer and utility sections. It is perceptible that results from both teams are the same.

V. Conclusion

In this article, we have proposed our idea of building a smart meter based on Automatic Meter Reading by forming a data communication channel between consumer and vendor using existing powerlines with a running voltage of 220V at 50 Hz. A microcontroller carries out the measurements of meter reading, and for data transfer, we have used PLC MODEM via powerlines. Real-time operation is necessary in the case of smart metering since it may overcome many problems associated with over-billing, energy theft, human blunders in taking readings, etc. Compared to other methods, this method is proved to be the most economical method since no additional hardware is required, no licensing, minimal losses, high availability of resources, and a high data rate. Furthermore, this method uses a data acquisition tool to continuously update the data received from the microcontroller in spreadsheet form for convenient data collection and analysis. There are more enhancement options to achieve ubiquity. It is possible to deploy this program over the public cloud to keep track of energy consumed by appliances. In a nutshell, we can say that this method will set a benchmark as one of the most effective and inexpensive methods.

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