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MODELING AND ANALYSIS OF POWER LINE COMMUNICATION USING PLC-KQ330

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Abstract*:*

In every aspect of human life, electronics play an important role. An electronic solution for remote meter reading and power supply control is a power line communication (PLC). The development of such a PLC-based system for the power distribution network may enable automatic electrical billing. Power lines that already exist and connect every home in a specific area are more advantageous because they don't need to be installed in order to build communication channels, making them quicker to establish. Less work is required, changes happen quickly, and the system is cost-effective. The frequency shift keying (FSK) modulation is used for data transmission across electric lines. Based on an FSK-KQ330, the power line communication system was created (carrier modulation and demodulation module). The system's main processor is an ESP32 microcontroller, while the modem module is PLC-KQ330. The system consists of an isolation circuit and a resonant circuit. Data signals can be sent via electrical lines using a master-slave arrangement. It is not just applicable to intelligent home systems but may also be used to remotely control intelligent switches and equipment. In this paper, the above-said process is totally automated, and communication is made possible entirely through the power line.

Keywords— *Power-line Communication (PLC), Automatic Meter Reading (AMR), Frequency Shift Keying (FSK), Liquid Crystal Display (LCD), Microcontroller (ESP32), Serial Monitor (SM), COOLTERM*.

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I. Introduction

Power lines use a specific form of communication called Power Line Communication (PLC). Power line communication alludes to the innovation which utilizes the current electrical cables to communicate analog or digital signals via a carrier at high rates [1]. The exclusive feature is that the system does not need to reconstruct the network; data transfer is possible as long as there is a cable [2]. The ongoing application regions are mostly gathered in the intelligent home, wire utilities, (for example, remote meter reading framework, road lighting remote observing frameworks, and so on) and modern intelligence (like different kinds of devices data acquisition) [3]. In fact, power line communication is presently not a point-to-point communications category, yet rather features the idea of an open organization structure. Each control hub (controlled gadget) forms a centralized network [4]. The framework utilizes the current electrical cables organization, without improving the organization link, which helps to save financial, material, and human resources. At the same time, it is reliable, and it is easy to be implemented and be extended [5]. Therefore, there is the significance for the research on the power line system[6]. In this paper the framework comprises the power line communication module, we used narrowband PLC module KQ330-FSK, which gives a connection to the primary transmission line (generally 220 v at 50-60 Hz) toward one side while the opposite end is associated with the meter conveying the load at transmitter section, at Receiver section one more PLC module is set up to interconnect the transmitter with the Receiver through fundamental power medium. The microcontroller and LCD are also connected at the transmitter end to display real-time readings about electricity usage [7].

II. Problem Identification

The power line was designed for the 50/60 Hz transfer of power; using it for the transmission of data (especially at high frequencies) poses certain technically challenging problems [8]. It's one of the most electrically contaminated settings, which makes it very hostile for the transmission of data signals [9]. High noise levels and erratic (or fluctuating) impedance and attenuation levels are the channel's defining characteristics. In addition, compared to cable or fiber-optic links, the line has less bandwidth [10].

Typically, power line networks are constructed by joining a range of conductor types and cross sections in a haphazard manner. As a result, the network encounters a wide range of characteristic impedances. Because of this, creating the filters for these communication networks presents some intriguing challenges [11].

III. METHODOLOGY

As shown in figure 1, the system is divided into two sections one is the consumer side where the meter is placed with an isolation circuit, i.e., optocouplers record the power consumed by loads connected subsequently, the digital electric meter acts as a source to generate pulses for the system then the output of energy meter feed to optocoupler. Similarly, the output of the optocoupler acts as input to the microcontroller to measure the readings. The actual measurement of readings 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 V_{AC}). The vendor section receives and displays the data using a workstation connected to the ESP-32 microcontroller. Further, this data is transferred serially to the workstation with installed data acquisition software to display the data in plain spreadsheet format.

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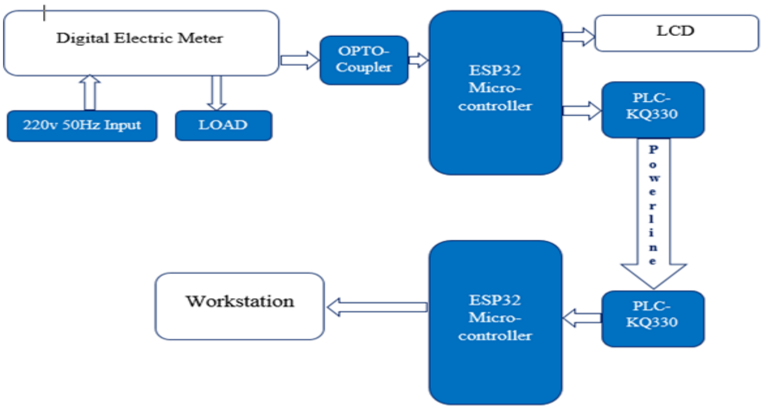

Figure 1: System Block Diagram

Table 1: Hardware and software specification

Item	Description	Item	Description
OS	WINDOWS 10	PLC MODEM	KQ330-FSK
Interface	UART, COM	Bandwidth	120KHz
Input	Voltage current	Speed	10kbps approx...
Power consumption	Kilowatt, KVAR	Opto-coupler	4N35
Frequency	50 Hz	LCD	SM
Baud rate	9600 bauds	Load	Any appliance support $220V_{AC}$
Modulation	FSK	COOLTERM	Data acquisition tool

A. **Hardware specification**

1) OPTO-COUPLERS (4N35)

OPTO-couplers are used for isolation and switching purposes. Since it is not necessary but efficient addition to prevent high voltage spikes in case of high-power transmissions [4].

Table 2: Opto-Coupler 4N35 PIN Description

Pin Number	Pin Type	Pin Description
1	A	Anode
2	C	Cathode
3	NC	Not Connected
4	E	Emitter
5	C	Collector
6	B	Base

2) PLC-KQ330 Module

It is a narrow-band PLC that could be a robust alternative for AMR, as compared to wireless communication. since for broadband applications PLC is not a convenient option, but in the case of long-range applications such as telemetry and grid applications, it is way more efficient proving cost-effective solutions better security, and flexibility at a moderate data rate [4]. In narrow-band PLC the data transmission rate is approximately 10kbps which is enough for remote communication [12]. the

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module we used here is KQ330, since we are using a single-phase system, it uses only a single carrier. The pin configuration of KQ330 is given below.

Table 3: PLC KQ-330 PIN Description

Pin Number	Connection on Consumer Side	Connection on Vender Side
1	Not Used	Not Used
2	Not Used	Not Used
3	Data Transmitter	Tx
4	Data Receiver	Rx
5	5v	5v
6	Ground	Ground
7	5v	5v
8	AC Phase/Neutral	AC Phase/Neutral
9	AC Phase/Neutral	AC Phase/Neutral

The data transmitted to the PLC Modem will be encoded with a 120 kHz carrier frequency and modulated with a 50 Hz AC signal (Frequency Modulation). Through a live AC 230V power line, the modulated signal can travel up to great distances. This module's AC terminals receive the modulated AC signal. As XC= 1/2fC (capacitor permits high-frequency signal) [13-14], capacitors permit only carrier frequency and prevent 50Hz signals. Capacitor-based demodulation at two levels is performed. Inductors and coils are utilized to block high-frequency signals, bypass low-frequency signals, and generate the 5V, 2A DC power source necessary for the modem. As we know that XL= 2fL, the inductor inhibits high-frequency impulses while permitting low-frequency signals. Using an optocoupler, the PLC Modem initially detects the zero crossing of a 220V sine wave. It injects a burst of 400-1200 bps data at 125 kHz-135 kHz and 5V after detection. Burst is accounted for as '0' and non-burst as '1'. PLC modem is equipped with a high pass filter that accepts the high-frequency burst [15-16].

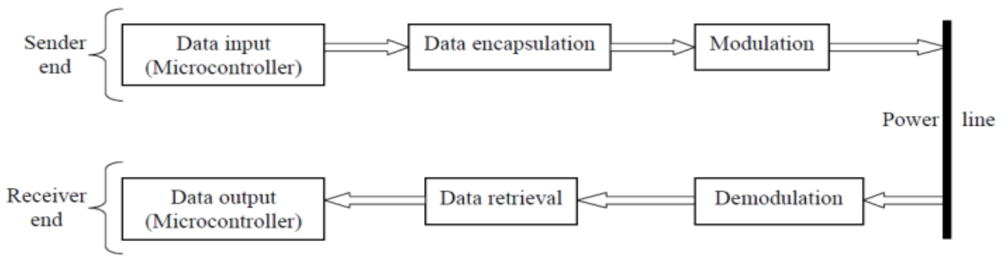

Figure 2: Block Diagram of PLC MODEM KQ330

3) Microcontroller (ESP32)

ESP-32 is a microcontroller that is 10 times faster and more versatile design also supports many features involving wireless connectivity like Wi-Fi, Bluetooth, etc.

4) LCD (16x2)

LCD is utilized in a variety of electronic applications [17]. It is frequently employed in numerous systems to display various statuses and metrics. LCD16x2 contains two lines of sixteen characters each. Each character consists of a 5x8 (column x row) matrix of pixels [18].

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5) Digital Meter

Digitally measures the amount of electrical energy consumed Also known as a digital or smart meter, an electronic power meter is a device that digitally measures the amount of electrical energy consumed by a business or electrical device [19].

B. **Proposed Method**

Our circuit estimates the real-time readings and displays these data, i.e., pulse count, Units, and Rupees, onto a serial monitor further, these data values can be delivered serially to the FSK-KQ-330 module which is modulated and injected to the powerlines carrying 220 V_{AC} at 50 Hz, at receiving side another FSK –KQ330 module placed that receives, demodulates, and proceed this data to the microcontroller where microcontroller displays the data on LCD and delivered serially over PC. To display this serially delivered data it is necessary to use some sort of application that transforms the data into proper sequence therefore, we will additionally use COOLTERM which is a data acquisition tool for the microcontroller that converts the data into a spreadsheet program.

C. **System Design**

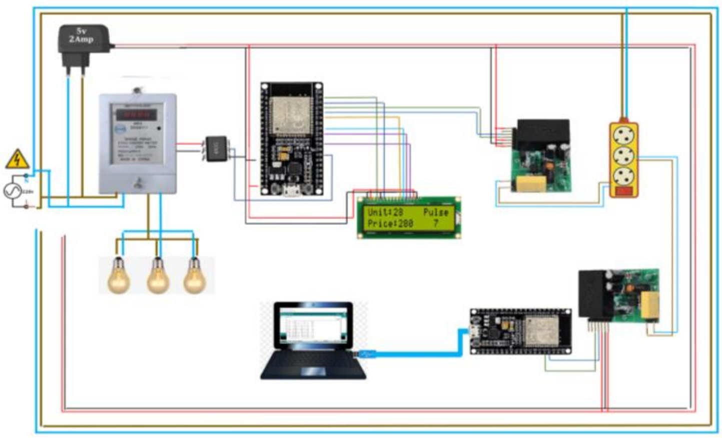

Figure 3: Graphical representation of Circuit

The system consists of an electric meter that is attached to loads; the loads can be any type of device, depending on their energy usage. An optocoupler that performs isolation between the AC and DC circuits, which is coupled to our ESP 32 microcontroller, is further connected to the electric meter circuit's LED, which blinks periodically depending on the load usage. In addition, optocouplers deliver pulses to the microcontroller, which records the pulses every time in accordance with the power consumed by the load. Additionally, we used a 16X2 LCD connected via the digital pins of the ESP 32 to display readings and pulse counts. Additionally, we also linked the ESP 32 output to an FSK-KQ 330 PLC MODEM, which contains a coupling circuit to couple the baseband output signal from the ESP 32 with a signal traveling via powerlines at a rate of 50 Hz. Since interference can be effectively reduced, the modem operates at 120 kHz. Powerlines utilize KQ33O as a baseband injector. Currently, powerlines serve as a medium for our baseband signal, which carries modulated data on a carrier signal of 120 kHz. To receive and demodulate the signal we have employed another KQ330 PLC MODEM that receives the modulated signal additionally containing a 50 Hz power signal. It first separates the power signal by means of a coupling circuit and then extracts the carrier from the baseband signal allowing the baseband signal to pass through. This baseband signal needs to be monitored and displayed for real-time operation. Therefore, the data acquisition tool (COOLTERM) is

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specialized for ESP 32 microcontroller to process analyze and display the data over a workstation/PC. Hence, to check the operation is working effectively it is necessary to match the pulse count price and units between the Customer section which is displayed via LCD, and the Vendor which is displayed via PC/Workstation.

1) Design of Transmitter Side

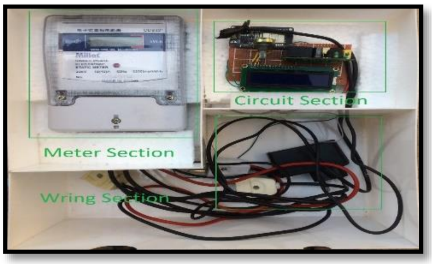

Figure 4: Design of Developed model (Transmitter Side)

Figure 4 shows the meter section and circuit section of the transmitter side. In which the digital meter is used to generate the data from the load in the form of pulses and the circuit section on the other side is used to display the real-time data which is coming from the meter side. The circuit section of the transmitter side is consisting of an optocoupler PLC and LCD to display and transmit real-time data to the powerlines.

2) Design of Receiver Side

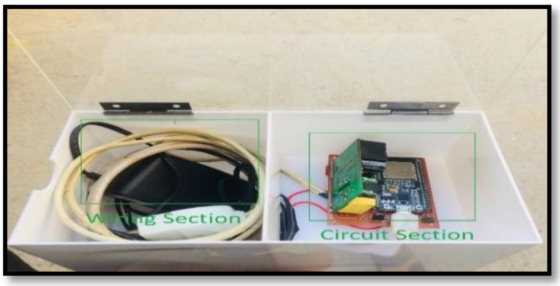

Figure 5: Receiver Section

Figure 5 shows the wiring and circuit section of the receiver side. In which the circuit section is used to recover the data which is transmitted from the transmitter side and display the result on the workstation. The circuit section of the receiver side which is consist of an Esp32 microcontroller and plc kq330 module to recover the data which is coming from the transmitter side.

IV. RESULTS

The parameters which are transmitted from the transmitter side and Received from the receiver side are Pulse Count, Unit Count, and Price.

A. LCD Display (Transmitter Side)

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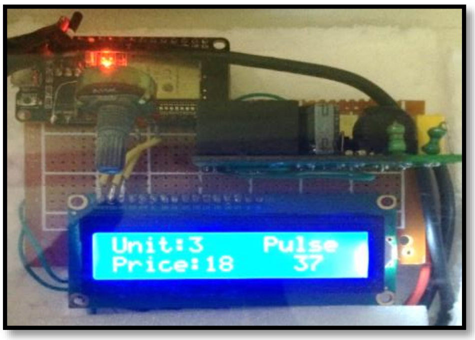

Figure 6: Transmitted data when the load is not connected

Figure 6 shows the LCD display which is accessed from the transmitter section and shows the result when there is no power consumption on the transmitter side. As described above parameters are transmitted from the transmitter side when the load is not connected to the energy meter, it shows the initial state, therefore, the parameters have no value in their respective columns, as results in zero. The results ensure that when there is no consumption of energy the results will be zero.

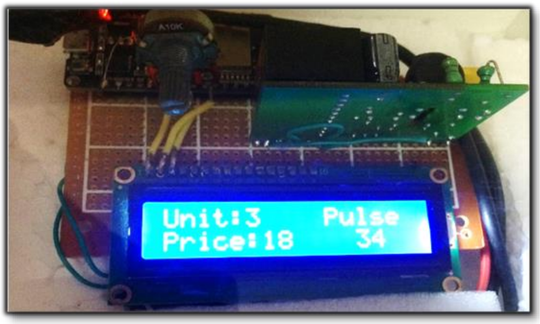

Figure 7: Transmitted data when the load is connected

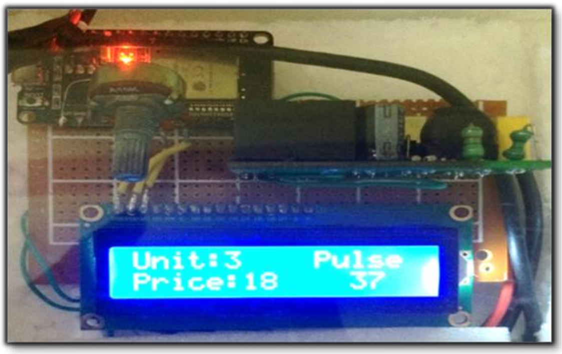

Figure 8: Continuous energy consumption

Figure 8 shows the LCD display which is accessed from the transmitter section and shows the result when there is continuous power consumption on the transmitter side. Parameters are transmitted from the transmitter side when the load is connected to the energy meter, it shows the continuous

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state, therefore, the parameters have value in their respective columns as result. The results ensure that when there is a consumption of energy the results will be variable.

B. ARDUINO Serial Monitor (Receiver Side)

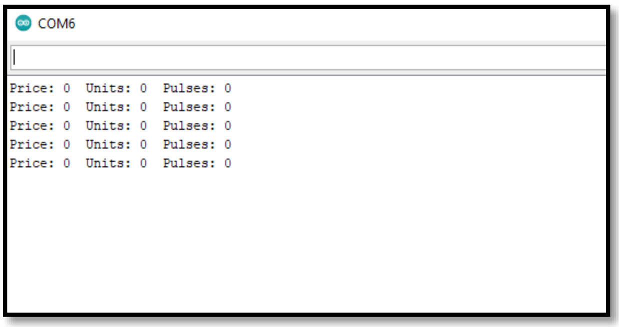

Figure 9: Received data when the load is not connected

Figure 9 shows the Arduino IDE serial interface which is accessed from the workstation the serial monitor is actively connected by UART communication with Port 6 of the workstation as shown in the figure. As described above parameters are transmitted from the transmitter side when the load is not connected to the energy meter, it shows the initial state therefore the parameters have no value in their respective columns as the result is zero. The results ensure that when there is no consumption of energy hence zero results will be received.

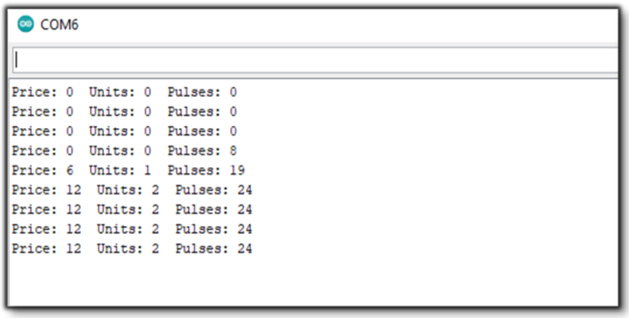

Figure 10: Received data when the load is connected

Figure 10 shows the Arduino IDE serial interface which is accessed from the workstation. As described above parameters are transmitted from the transmitter side when the load is connected to the energy meter, it shows the continuous state therefore the parameters have values in their respective columns as result. The results ensure that when there is a consumption of energy, the variable result is received.

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C. COOLTERM Data Acquisition

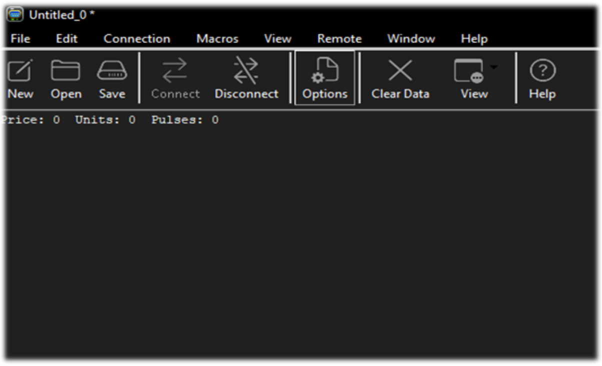

Figure 11: COOLTERM interface Result

Figure 11 shows the COOLTERM interface which is accessed from the workstation the serial monitor is actively connected by UART communication with Port number 6 of the workstation as shown in the figure. As described above parameters are transmitted from the transmitter side when the load is not connected to the energy meter, it shows the initial state, therefore, the parameters have no value in their respective columns as result is zero. The results ensure that when there is no consumption of energy the results will be zero.

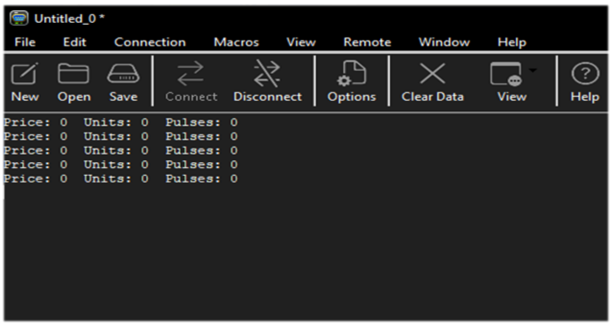

Figure 12: COOLTERM interface Results when the load is not connected

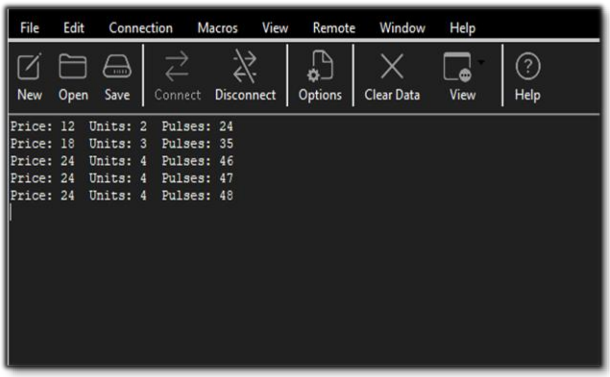

Figure 13: COOLTERM interface Results when the load is connected

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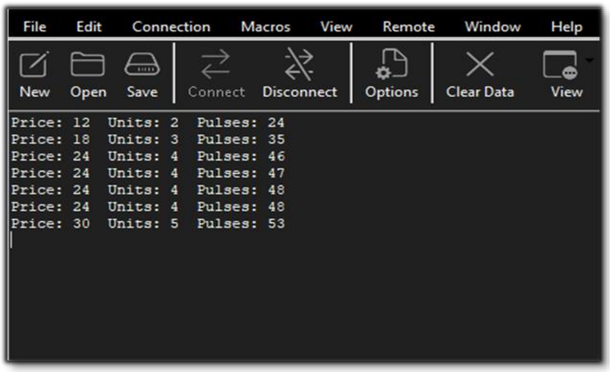

Figure 13: Continuous energy consumption

Parameters are transmitted from the transmitter side when the load is connected to the energy meter, it shows the continuous state therefore the parameters have value in their respective columns as result. The results ensure that when there is a consumption of energy, the received results will be variable.

V. CONCLUSION

In this article, we have outlined our concept for creating a smart meter based on automatic meter reading that would use existing powerlines to create a data communication path between the customer and the vendor while operating at a running voltage of 220V at 50 Hz. Microcontrollers are utilized to measure meter readings, while PLC MODEM is used to transport data over powerlines. Smart meters must operate in real-time in order to avoid issues like overbilling, energy theft, human error when taking readings, and other issues. This method doesn't require any additional hardware, requires no licenses, incurs little losses, and has a high availability of resources and a high data rate. Additionally, this approach uses a data acquisition application to automatically update the spreadsheet-formatted data received from the microcontroller for easier data gathering and analysis. There are other upgrade options available to achieve ubiquity, including the option to distribute this application over a public cloud to monitor energy usage by appliances. In a broad sense, we can claim that this strategy will become recognized as one of the most efficient and affordable ones.

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