STUDY OF DIFFERENT MODULATION TECHNIQUES FOR A SMART GRID BASED COMMUNICATION MANAGEMENT SYSTEM

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Abstract— **In the current generation, a new concept of Smart grid has been introduced to overcome the drawbacks of existing power system. It explains the lack of software programs that simulate the Smart grid principles. Smart grid system makes it possible to have an intelligent communicating network by integration and combination of electrical power grids. This paper describes the transfer of data obtained from smart meters to the collector point through Power Line Communication (PLC) channel and retransmission of the data from collector point to the utility. It further explains the modulation of data propagating through PLC using three different modulation techniques and selection of the best possible modulation technique for the efficient working of the system.**

Keywords— Smart grid, Power Line Communication (PLC), Modulation, Constellation diagrams

I. INTRODUCTION

Existing grid is electromechanical, that enables only one way communication involving centralized generation. It requires manual monitoring and manual restoration in case of any failure of equipment due to natural disasters, weather conditions, environmental conditions etc. Blackouts are likely to occur in these grids [1]. In order to eliminate these problems it is necessary to look for an alternative that can function in any worst condition. Thus the new concept of Smart grid has emerged to solve the issues pertaining to the existing grid [5].

Smart grid is digital that enables bidirectional communication involving distributed generation with sensors distributed throughout the system thus making the system prepared to address the challenges in any emergency condition [6]. It is programmed such that it is self-monitoring and self-healing. Blackouts are eliminated in smart grids. Smart grids improve the resiliency of power system [2]. Due to its feature of two way communication it facilitates automatic rerouting during components failure. Smart grid technologies detect and isolate the parts that suffer from outages thus preventing large scale blackouts and making the system smarter [3]. As the population is growing rapidly the demand for energy is more than the supply. This has led the existing system to be inefficient in fulfilling the energy desires of people. Due to the advanced features of Smart grids it is possible to overcome issues pertaining to energy demand [4]. In the present situation smart grids can be regarded as a boon.

Smart grids are equipped with smart meters that indicate the energy consumed, power utilized etc. through which users get to know the energy requirements thus allowing the users to keep track of whole process. Smart grids include intelligent controllers for fault monitoring. It is possible to control the system automatically through smart grids [3].

Communication plays an important role for the information transfer from the point of generation to the utility [8]. At the utility data is stored for further analysis. Various communication techniques can be used for transferring information from generation point to final consumers by modulating the data obtained from smart meters and propagating the same through power line communication (PLC) channel [9].

PLC is like any other communication technology where the data sent by the sender is modulated, injected onto the medium and to read the data at the other end the receiver has to demodulate the data. An important feature of PLC is that it re-uses existing wiring so the necessity of extra cabling is eliminated [12]. Power line communication technology has proven to be a robust and cost-optimized solution in many parts of the world in large deployments of smart meters [13].

In this paper PLC is used as the medium through which data obtained from houses is propagated from the central concentration point to the utility. In this paper modulation techniques such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM) are used for propagation of data obtained from smart meters through PLC.

II. BENEFITS OF SMART GRID

a. Helps measure and reduce energy consumption and costs.
b. Facilitate real-time communication between the consumer and utility.
c. Provides new opportunities for utility companies.
d. Ensures the utilization of energy to the maximum without being wasted.
e. Improves the reliability and efficiency of the system.
f. Improves the overall performance and productivity of the system.

III. METHODOLOGY

The system consists of smart meters connected to a central point with PLC as the medium. Information collected from home network to an access point needs to traverse to a central point. The overall system structure is depicted in Figure 1. Through free space the readings are then retransmitted, further utility receives these readings. Any number of houses can be tested using this system.

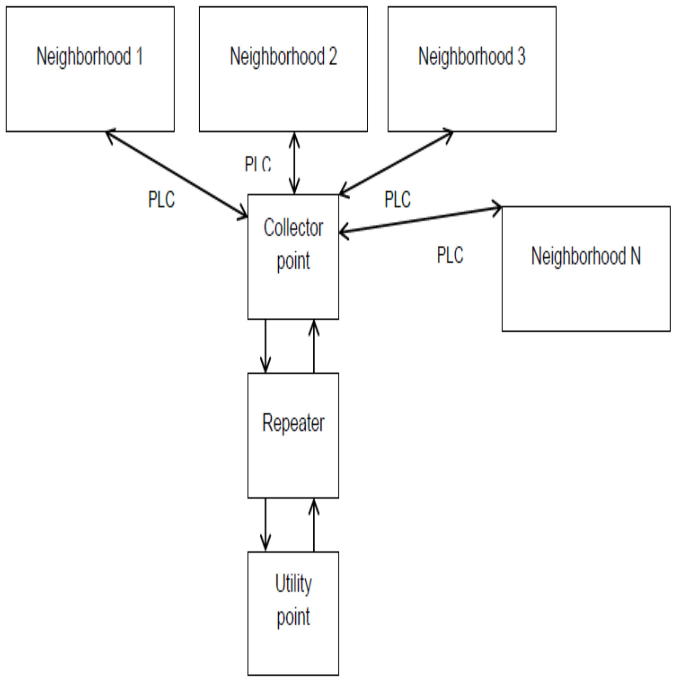

Figure 1: Structure of Smart grid segment

The system is designed such that it is user-interactive. The house readings obtained from the point of generation until reaching the utility is illustrated with figures by the system. This feature enables the user to track the whole process easily. The implementation of the system is shown in Figure 2.

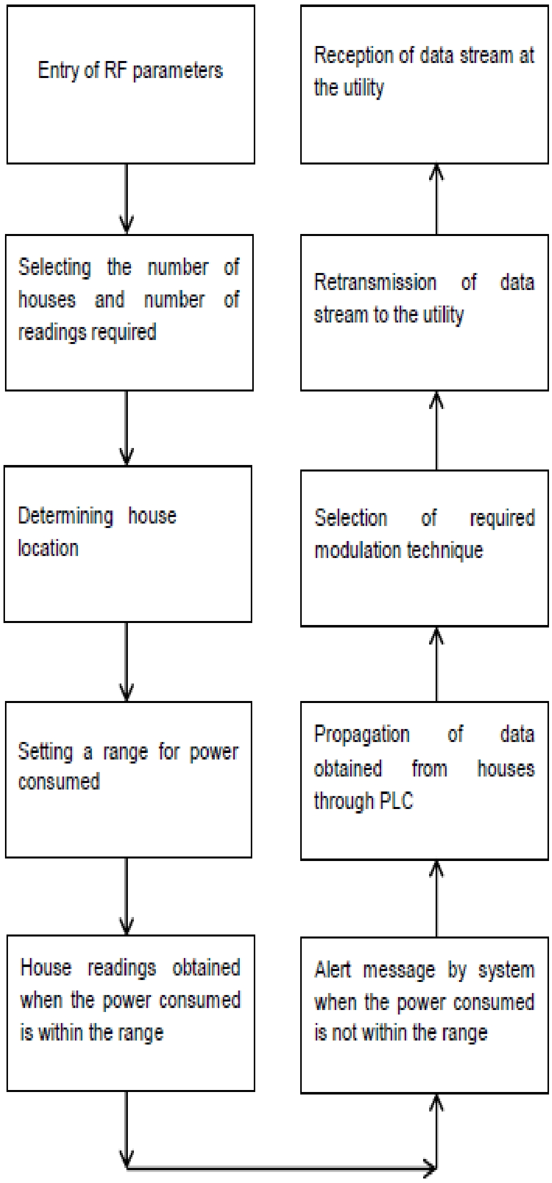

Figure 2: Implementation of the system

IV. RESULTS AND DISCUSSIONS

The system is programmed such that it asks the user to enter the RF parameters. The RF parameters considered here include operating frequency, distance between the transmitter and the receiver, gain of transmitting and receiving antenna and the amplitude of transmitted power. For illustration, let the operating frequency be 15GHz, distance between the transmitter and the receiver be 7 km, gain of transmitting and receiving antenna be equal to 2.0 and the amplitude of transmitted power be 4.6V. Figure 3 shows the output on entering the RF parameters mentioned above.

```
Enter operating frequency(GHz):=15
Enter the distance(km):=7
Enter the gain of transmitting antenna:=2.0
Enter the gain of receiving antenna:=2.0
Enter the amplitude of transmitted power:=4.6
   4.6655e-05
```

Figure 3: Entry of RF parameters

After entering the RF parameter values in the system, the system further asks for the number of readings required and the number of houses to be tested in the respective neighborhoods. For illustration the number of readings is chosen as 3 and number of houses is chosen to be 1, 2, 1 in neighborhood 1, 2 and 3 respectively. Selection of number of readings and number of houses to be tested is as shown in Figure 4.

```
Enter the number of readings required:=3
Enter the number of houses for neighborhood 1:=1
Enter the number of houses for neighborhood 2:=2
Enter the number of houses for neighborhood 3:=1
```

Figure 4: Selection of number of readings and number of houses

```
Enter the required house number:=2
Enter the required neighborhood number:=1
```

Figure 5: Determining location of house and its neighborhood

On selecting the number of readings and number of houses in each neighborhood as shown in Figure 4 and their respective location as indicated in Figure 5, the corresponding PLC response is obtained as shown in Figure 6 and Figure 7.

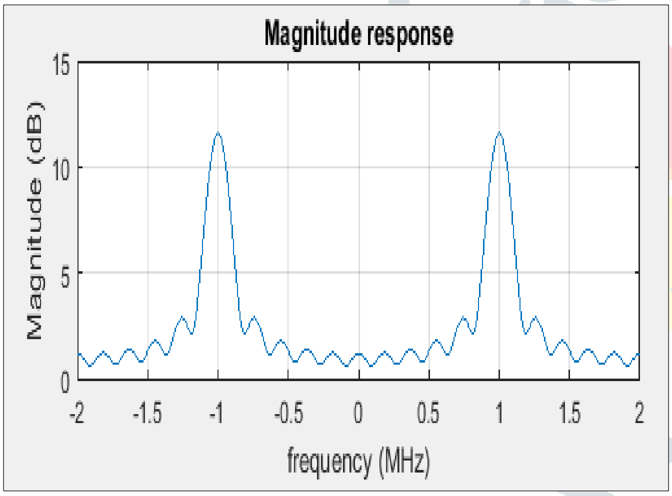

Figure 6: Magnitude response of the PLC

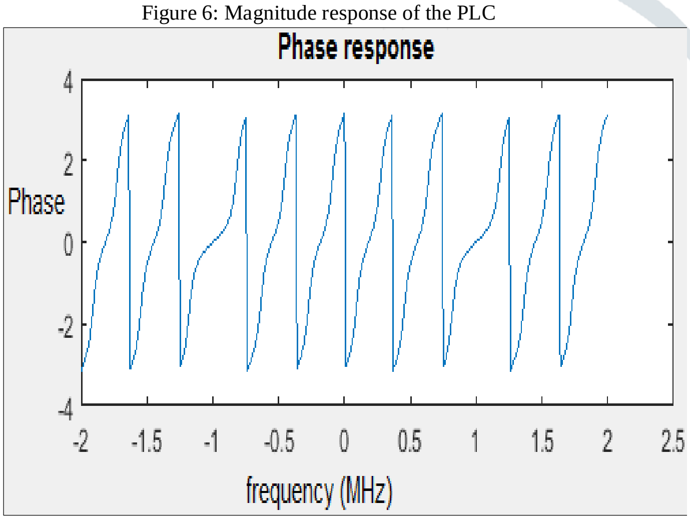

Figure 7: Phase response of PLC

The system now sends the data of houses to the utility. In order to get a clear idea of the power consumed by the houses a range of 500-900 watt hour is set. System is programmed such that it will display the house readings whenever the power consumed is within 500-900 watt hour else alert message will be displayed. If the power consumed is less than 500 watt hour then the system displays an alert message indicating power consumed is below the threshold. If the power consumed is more than 900 watt hour then the system displays an alert message indicating power consumed is more than the threshold. Similarly for every house in the selected neighborhood the above procedure is followed. Thus the user will be able to get an idea of the power utilization. Figure 8 shows the readings obtained while testing the house whose power consumption is within the range of 500-900 watt hour.

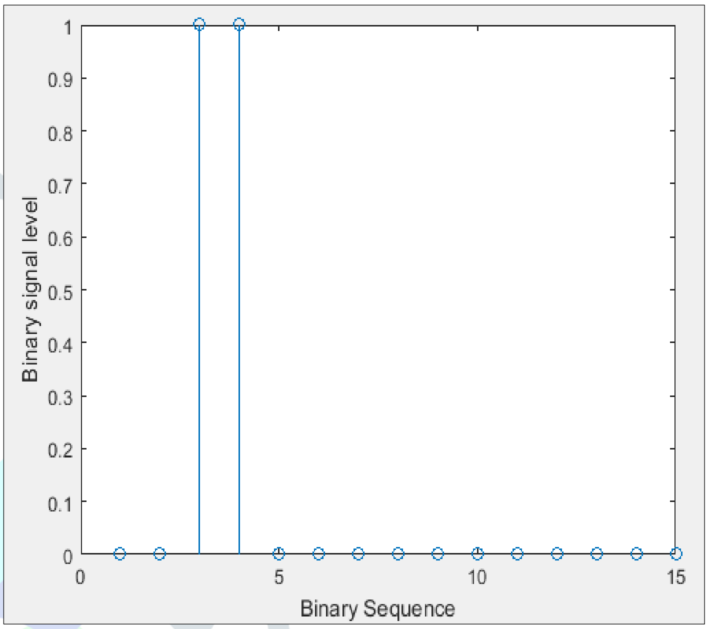

Figure 8: First house readings

Display of alert message by the system when the power consumed by the houses is not within the range of 500-900 watt hour is shown in Figure 9 and Figure 10.

```
   200

power consumed is below the threshold
   400

power consumed is below the threshold
```

Figure 9: Display of alert message by the system when the power readings obtained are below the threshold

```
        1000

Overconsumption of power
        1200

Overconsumption of power
        1400

Overconsumption of power
        1600

Overconsumption of power
        1800

Overconsumption of power
        2000
```

Figure 10: Display of alert message by the system when the power readings obtained are above the threshold

The system then sends the binary information obtained from houses through PLC thereby modulating the data so that it can be transmitted for a longer distance.

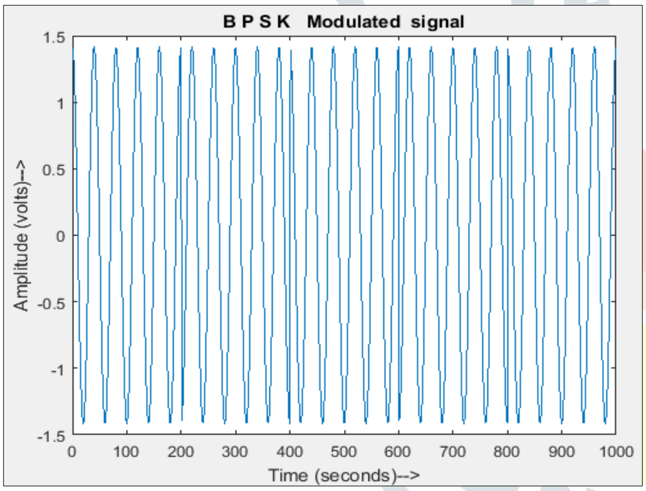

Figure 11: BPSK Modulation

Data propagating through PLC can be modulated using three different modulation techniques. In this system modulation is achieved using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM).

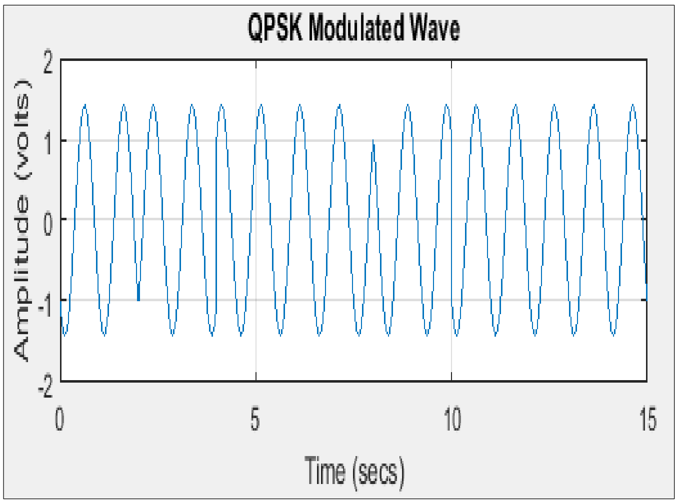

Figure 12: QPSK Modulation

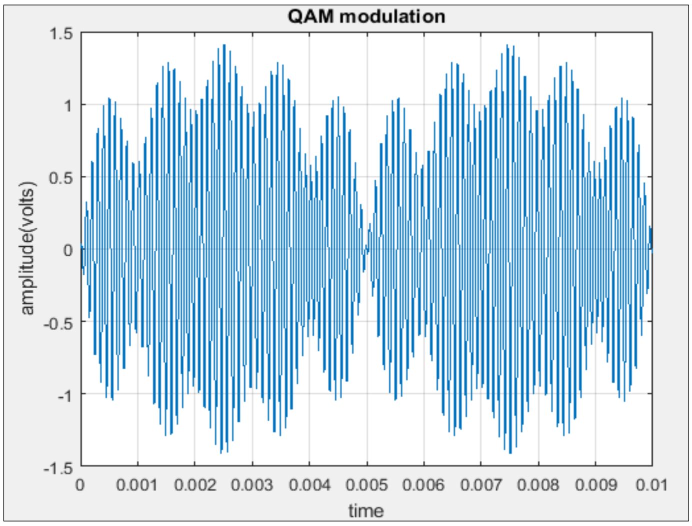

Figure 13: QAM Modulation

The modulation techniques used in this system is shown in Figures 11, 12 and 13. BPSK Modulation is shown in Figure 11, QPSK Modulation is shown in Figure 12 and the QAM Modulation is shown in Figure 13. For the successful operation of the system selection of best among the three modulation techniques is essential. Comparison of BPSK, QPSK, and QAM helps in choosing the required modulation technique for the system operation. Comparison of modulation techniques can be done on the basis of various factors. In this paper comparison of BPSK, QPSK and QAM is done on the basis of Constellation diagram.

A Constellation diagram is a collection of signal points. Constellation points are the decision points used to recover original binary symbols. Labeling of constellation points is done in such a way that by assigning to all points a bit pattern in order to maintain constant amplitude. Performance of any modulation technique is dependent on the labeling method chosen for mapping constellation points.

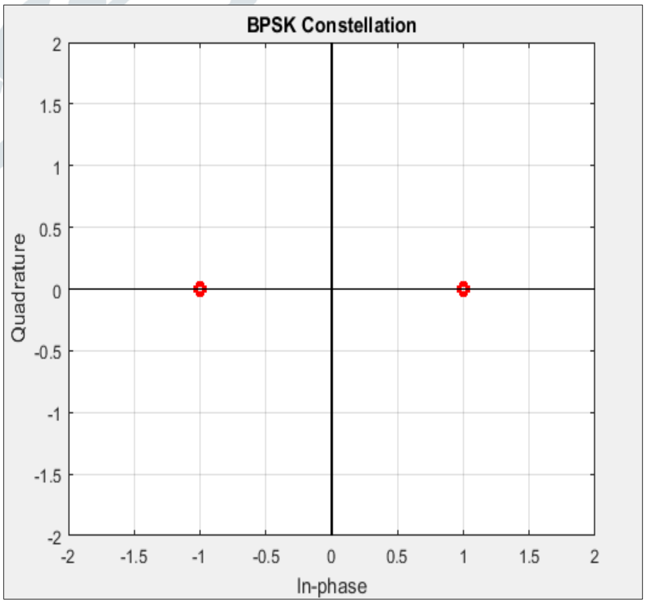

Figure 14: Constellation diagram of BPSK

Constellation diagram of BPSK modulation technique is shown in Figure 14 which has two constellation points.

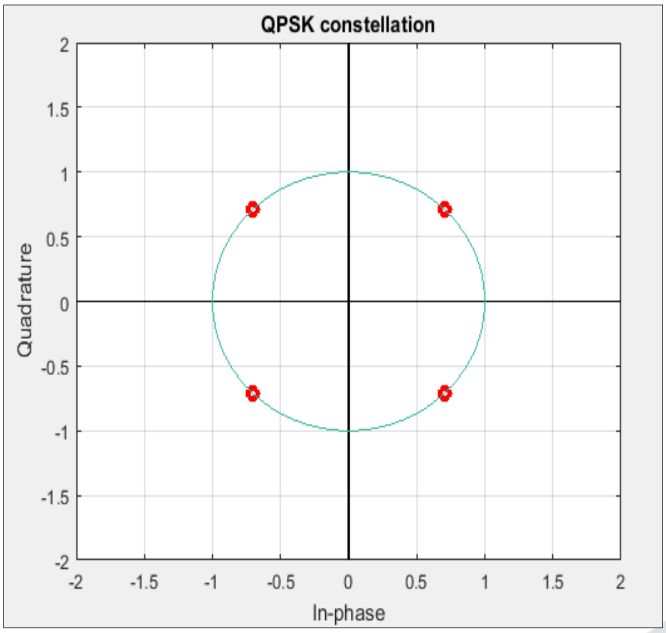

Figure 15:Constellation diagram of QPSK

Constellation plot of QPSK modulation technique is shown in Figure 15. QPSK has 4 constellation points.

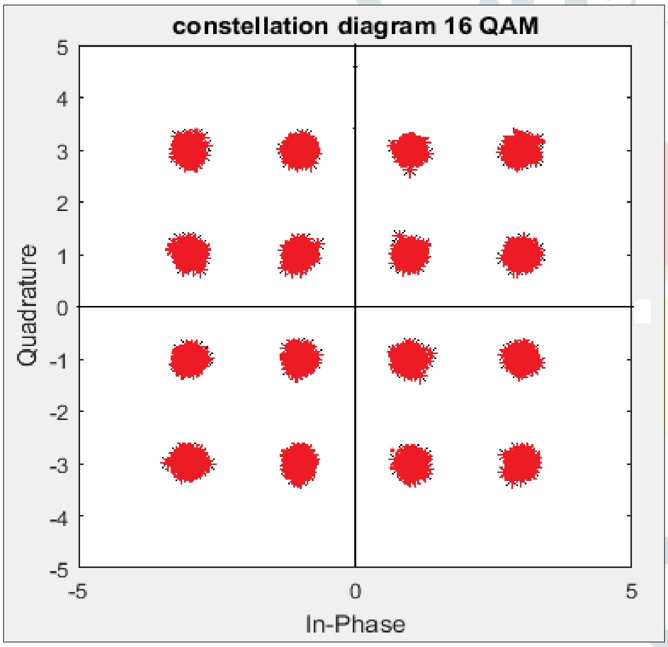

Figure 16: Constellation diagram of 16 QAM

Constellation plot of 16 QAM having 16 constellation points is shown in Figure 16.

As the order of QAM increases the number of constellation points increases. For higher order QAM i.e. for order of QAM greater than 16 there are more constellation points. The number of constellation points depends on the number of symbols to be transmitted at once. Therefore as observed in the Constellation diagrams of BPSK, QPSK and 16 QAM it is clear that more symbols are transmitted in 16 QAM or in other words more data is transmitted and hence data rate of 16 QAM is very high compared to BPSK and QPSK. In this paper Constellation diagrams clearly indicate the amount of data to be transmitted. BPSK has only two constellation points therefore data that can be transmitted using BPSK modulation is very less. QPSK has four constellation points therefore data that can be transmitted using QPSK modulation is more when compared to BPSK. Constellation diagram of 16 QAM has 16 constellation points so the amount of data transmitted is more than QPSK and BPSK. Thus it can be concluded that QAM is more suitable modulation technique that can be used in this system.

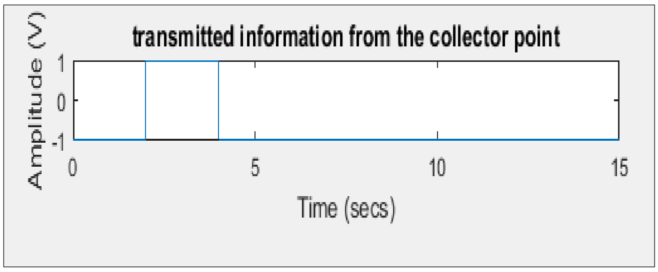

Figure 17: Transmitted information from the collector point to the utility

After the modulation of data using best possible modulation technique, the same data is transmitted to the utility from the central concentration point. Figure 17 indicates retransmission of data stream from the collector.

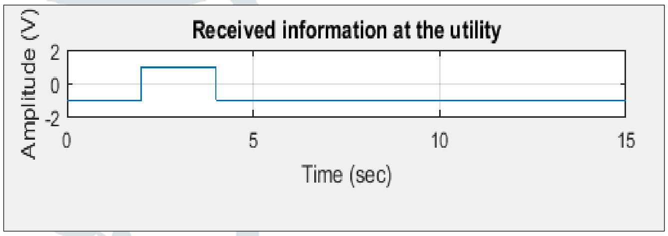

Figure 18: Received information at the utility

The data stream sent from collector point is received at the utility as shown in Figure 18.

V. CONCLUSION

Collecting the data from smart meters and propagating the same through PLC, thereby retransmitting it through free space to the utility from the collector is successfully performed using this system. The required modulation technique is selected among BPSK, QPSK and QAM on the basis of Constellation diagram. More the constellation points more is the data transmitted thus high is the data rate. From the Constellation diagrams of BPSK, QPSK and QAM it is observed that QAM can transmit more information than QPSK and BPSK due to the fact that it has more constellation points. QPSK can transmit data more than BPSK but less amount of data than QAM. Hence from the simulation results it can be concluded that QAM is the best choice for modulation.

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