Automatic Meter Reading For Smart Metering By Using QPSK Modem With PLC Channel and GSM Modem.

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Abstract- *In ARG18 Modem using GSM/GPRS Communication for Automatic Meter Reading (AMR) applications. These AMR systems have made substantial progress over the recent years in terms of functionality, scalability, performance and openness such that they can perform remote metering applications for very demanding and complex systems. Using QPSK Modem with Power Line Carrier Communication for Smart Metering thereby implementing Smart Grid Technology for Rural Smart Micro Grids and thus simulating the design successfully using MATLAB software. Also to identify the advantages and disadvantages of using QPSK Modem with PLC (Power line Communication) Channel over the ARG18 Modem with GSM/GPRS communication.*

Key Words*: Automatic Meter Reading (AMR), QPSK Modulation and Demodulation; Power Line Communication; GSM Modem; Smart Micro-Grid; Matlab/Simulink.*

I. INTRODUCTION:

Energy generation is one of key factors for the economic development of a country. Smart metering uses digital technology to improve Reliability, Security and efficiency of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed generation and storage resources. Since the energy supplier knows the amount of generated electricity and its flow through out electrical substations, the energy supplier can use this AMR to detect energy loss and fraud. Automatic meter reading (AMR) is a technology which automatically gathers data from energy, gas, and water metering devices and transfers it to the master station in order to analyze it for billing purposes. Data are read remotely, without the need to physically access the meter[1]. The advantages include reducing peak demand for energy, supporting the time-of-use concept for billing, enabling customers to make informed decisions, and reducing the cost of meter reading. Various Communication technologies in AMR have been proposed recently, including mobile technologies, based on radio frequency, transmission over the power line, or telephonic platforms (wired or wireless). Utilizing an existing cellular network for data transportation requires no additional equipment or software, resulting in a significant savings in both time and capital. The inherent communication infrastructure presented by Power Line Carrier(PLC), which significantly reduces the cost of building a new communication network, makes PLC a favorable solution for AMR systems[2]. However, since the low-voltage power supply networks are not designed for communications and bandwidth is limited, PLC alone can hardly scale to support a large network in addition to other shortcomings. The availability of wireless communication method such as GPRS will play an important role in future for transmitting data at a favorable price from residential buildings to central billing centers and providing extra services for the user. With the advantages of high-speed, unlimited transmission range, GPRS is very suitable for the power applications.

II. AMR SYSTEM ARCHITECTURE

A. Components of AMR System:

i. Electrical Meter:

An electronic device that measures the amount of electrical energy supplied to a residence or business. It is electrically fed and composed of electronic controllers. It incorporates an interface which allows data to be transmitted from the remote terminal to the collector.

ii. Collector:

A collector is able to store and to process received information from many electrical meters according to the command from the upper concentrator. It can also forward the processing data to the concentrator. The number of electrical meters controlled by a collector can be determined by the specific applications.

iii. Concentrator:

On the one hand, a concentrator sends commands to collector to receive meter readings periodically, such as on a monthly basis. On the other hand, it transmits meter readings as well as load survey data to the database of central station for further analysis.4.

iv.Central Station (Control center):

Through the layered communication network, the large capacity computer manages every part of the AMR system such as reading meters periodically or real-time checking status of each concentrators making fault diagnosis and alarming. Furthermore, tariff calculation and collection could be realized by interconnection with the power supply system.

v. Meter Interface Module:

The AMR system starts at the meter. Some means of translating readings from rotating meter dials, or cyclometer style meter dials, into digital form is necessary in order to send digital metering data from the customer site to a central point.

The AMR Architecture as shown in Fig.1 below.

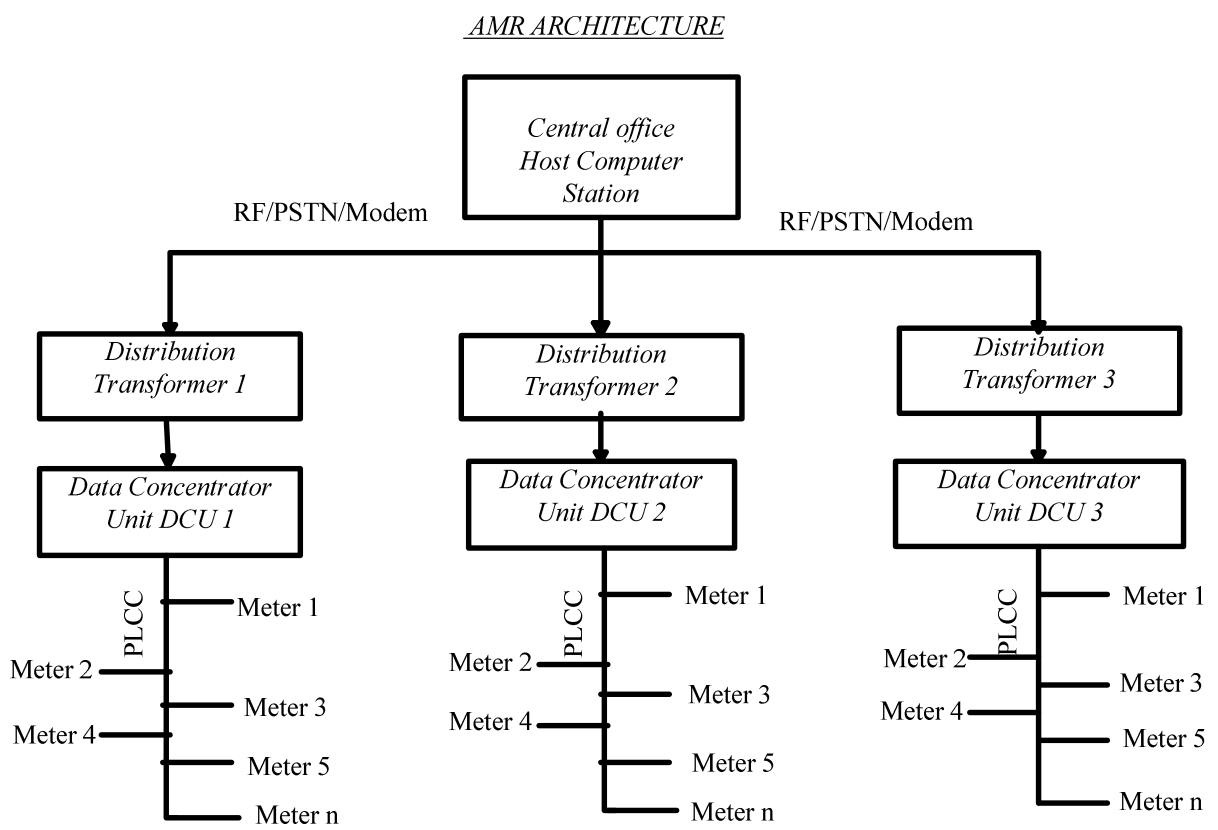

Fig.1. AMR Architecture

B. GSM Based Communication:

A single stage of communication between Meter and Central station through GSM Modem. Utilizing an existing cellular network for data transportation requires no additional equipment or software, resulting in a significant savings in both time and capital. Cellular technology uses an encryption technique to prevent an outside source from receiving the transmitted data [3]. The Cellular network provides full two-way communications, allowing scheduled reads, Demand reads, alarm and event reporting, power outage reporting and power restoration reporting. The GSM Communication in AMR as shown in Fig.2.

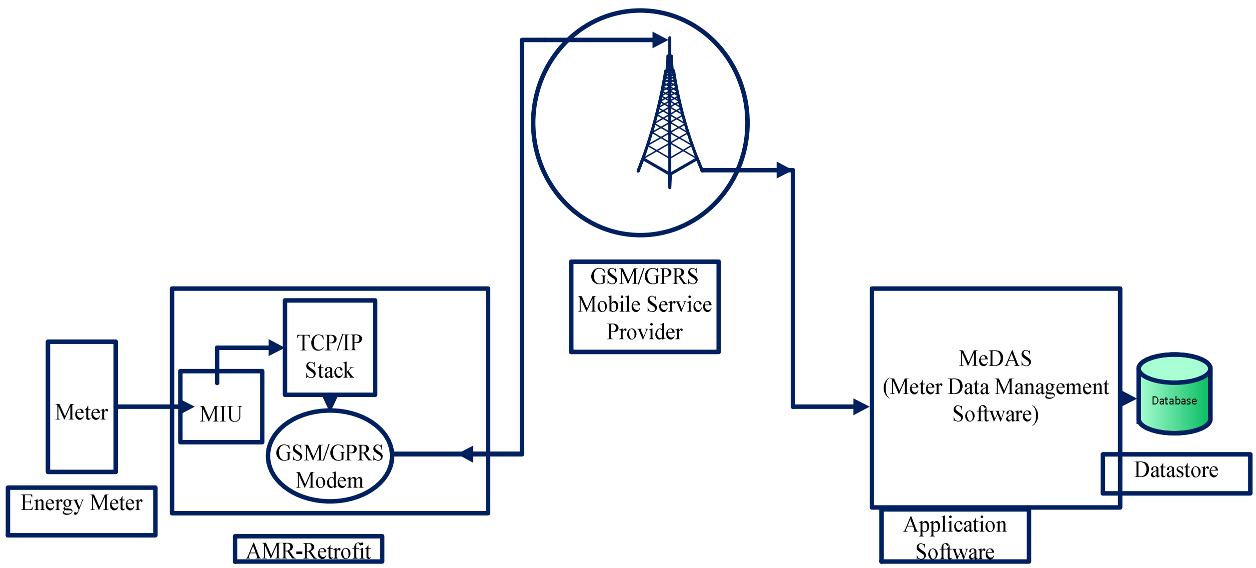

Fig.2. GSM communication in AMR

C. PLCC Based Communication:

Power Line Communication is a communication technology that enables transferring data over AC power wiring. So there is no need to any additional wiring for communication network. Communication is achieved by adding a high frequency signal at low energy levels over the electric signal and the second signal is propagated through the power network to the receiving end [4]. Electrical devices can be easily interconnected and managed through power lines. Power line communication is appealing because it uses the existing power line infrastructure. The basic block diagram of QPSK based on network for proposed Smart Micro-Grid is shown in Fig.3. Data server was developed to allow multiple PLC connections to smart grid and flexible control over the message exchange between users and smart micro-grid. The smart is a digitally-enhanced version of the traditional grid, where deployed advance communication technologies and computing technologies. In Fig.3, coordinator of HAN device is connected with home appliance and smart meter. Smart meter is connected with Smart micro-grid by QPSK based PLC Modem and coupling circuit. The control unit manages HAN network configuration, as well as exchanges information between each home appliances and PLC network. In this gateway, power utility company is able to be connected to not only smart meter but also to the existing electric appliances in home via PLC network [5]. Technologies are now widely available that bi-directional communication for PLC network. So PLC network is well-suited to rural areas and cost effective solution to communicate between power utility companies and its customers where there is no other communication networks exist.

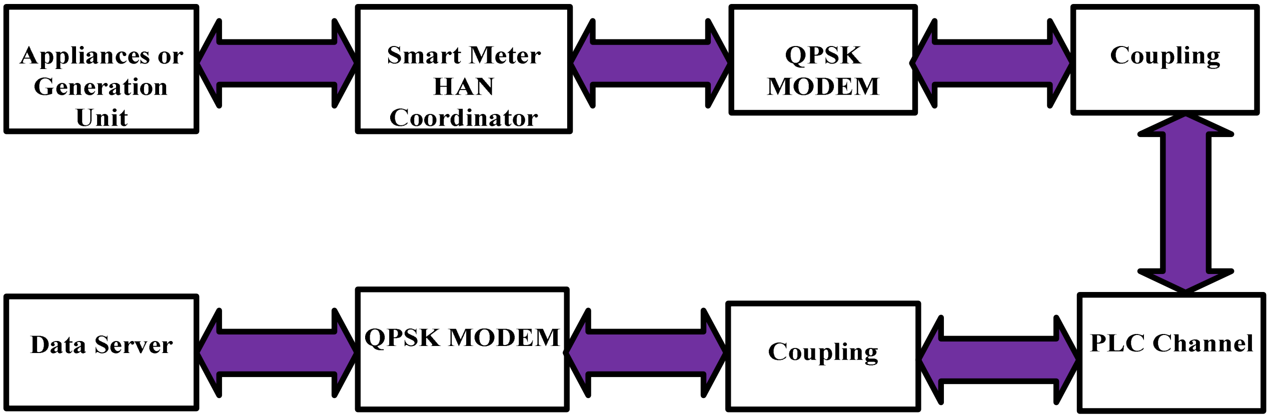

Fig.3. Block Diagram of QPSK Based on PLC Network For Smart Micro-Grid

The PLCC Communication in AMR as shown in Fig.4.below.

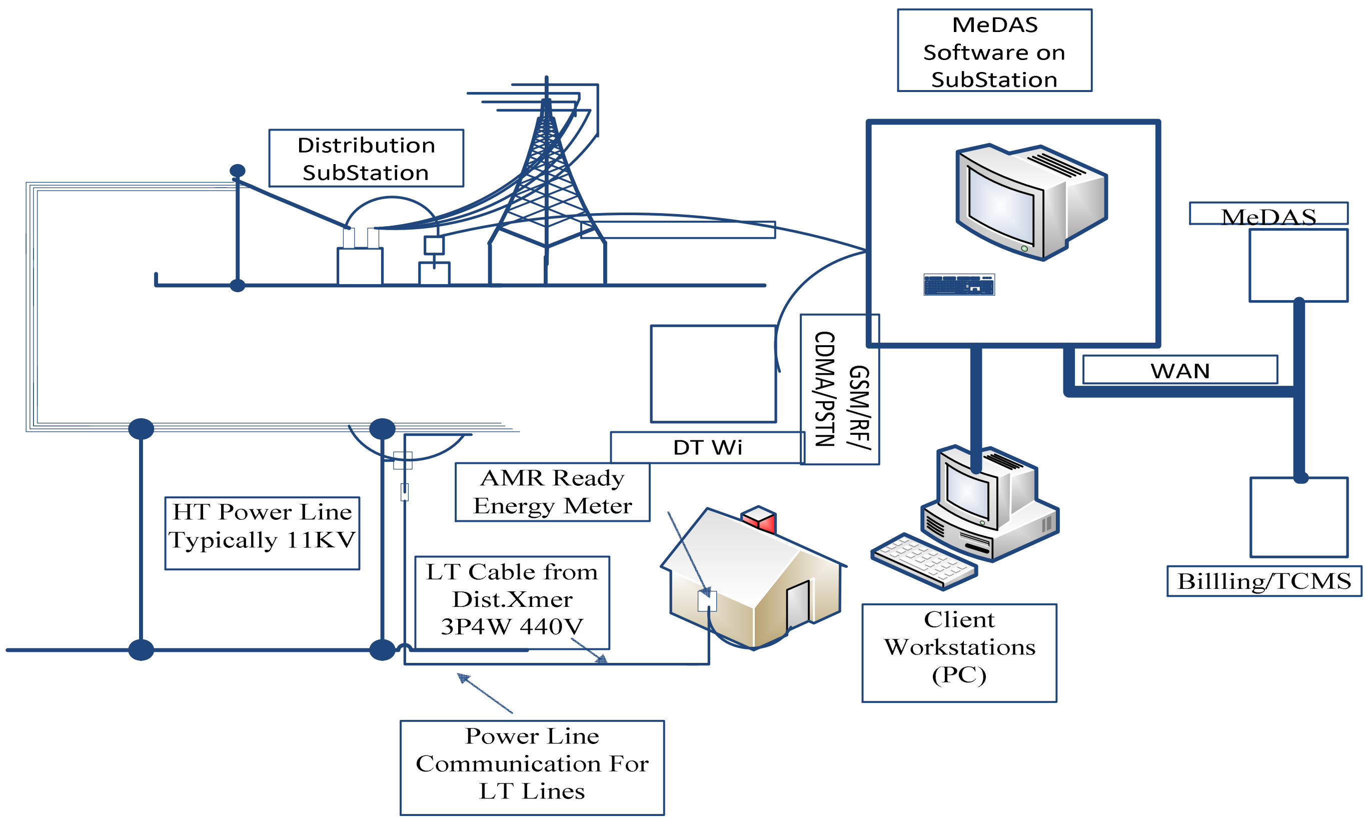

Fig.4. PLCC Communication in AMR

The Data Concentrator sits on the loop of secondary of the distribution transformer. It is the 'modem' system of the setup. It modulates and demodulates the data that is to be sent through the power line. QPSK modulation technique is followed by the unit. It is placed at the consumer as well as utility side for transmission and reception and vice versa. Serial communication method is used for the power line transfer. It collects meter readings from all the meters using Power Line Communication System at predefined intervals. The DCU and all the meters connected to it can be considered as a subsystem of the HCS. The subsystem is set up with a DCU monitoring the low voltage power zone downstream of a Distribution

Transformer as shown in Fig.2. PLCC Best Suited for LT 440 V network for detecting outages, tamper events and performing remote disconnect. Uses same power lines as communication media, so ideally suited for rural/ agricultural connections. Communication on HT side can be implemented via a choice of GSM, CDMA, RF or PSTN as shown in Fig.4. PLC unit consists of a single PCB which converts CF pulses of Electronic Energy Meters to Electrical pulses, accumulate them and generate a meter reading with help of Microprocessor[6]. Microprocessor converts this data into Power Line Modulation. Existing Meter Reading, Meter Constant and Meter ID is stored in NV RAM of Micro Controller, before Retrofit is made operational. One unit is incremented when Retrofit senses the pulses equal to Meter constant. The incremented unit are stored in the NV RAM of the Micro Controller.

III. Power Line Characterization and Modeling:

Power Line network is not initially designed to carry information. But reduced operation and management with initial cost expenditures. However it has also disadvantages such as noise and signal attenuation. Distance is another issue that effects the power line communication performance [7]. The inductance, resistance, capacitance and conductance must be measured for characterization and modelling of communication channel. According to the line theory of pair power cable of characteristic impedance and propagation constant can be calculated by following equations.

$$Z_L = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \quad (1)$$

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} \quad (2)$$

Where,

Z_L= Characteristic impedance

γ= propagation constant

ω= angular frequency

R = resistance per unit length

L = inductance per unit length

G = conductance per unit length

α = attenuation constant and

β = phase constant

Propagation constant and characteristic impedance depend on R, L, G and angular frequency but not length of line.

i. Design of QPSK Modem with PLC Channel:

Digital Modulation is a process that impresses a digital symbol on to a signal suitable for transmission on a wired or wireless medium in order to receive that signal at receiving end correctly without any loss of information. The bandwidth of this modulated signal depends on band signal and modulation scheme to be used. Digital symbols sequence is used to high frequency carrier signal. The three main digital modulation types are Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK). The combination of two orthogonal Binary Phase Shift Keying (BPSK) modulated signals from Quadrature Phase Shift Keying (QPSK). The QPSK Modulation system is the base structure of wired and wireless communication such as wired modem,3G, WiFi and WiMAX. Advantage of this technique is to reduce the utilized bandwidth of QPSK system which is highly useful in communication technology. In QPSK method, data bits are grouped into pair, and each pair is represented by particular waveform called a symbol. QPSK uses four points on the constellation diagram as shown in Fig. The QPSK signal is mathematically described by the following equation:

$$S_i(t) = Acos(2\pi f_c t + \theta_i), \quad 0 \leq t \leq T, \quad (3)$$

i=1,2,3,4

Where, A is the carrier amplitude, f_c is the carrier frequency and θ_i is the phase angle of carrier. Equation (4) can be written as

$$S_i(t) = Acos\theta_i cos2\pi f_c t - Asin\theta_i sincos2\pi f_c t$$

$$S_t = S_{i1}\varphi(t) + S_{i2}\varphi(t) \quad (4)$$

Where,

$$\varphi_1 = \sqrt{\frac{2}{T}}\cos(2\pi f_c t), \ \ 0\leq t \leq T$$

$$\varphi_2 = \sqrt{\frac{2}{T}}\sin(2\pi f_c t), \ \ 0\leq t \leq T$$

$$S_{i1} = \sqrt{E}\cos\theta_i$$

$$S_{i2} = \sqrt{E}\sin\theta_i$$

$$\theta_i = \tan^{-1}\frac{S_{i2}}{S_{i1}}$$

So, QPSK signal can be express as:

$$S(t) = \frac{A}{\sqrt{2}}[I(t)\, cos(2\pi f_c t) - Q(t)\, sin(2\pi f_c t)] \quad (5)$$

Output of QPSK waveform with four different phase shift is as shown in Fig.5. Each symbol of original has a different phase angle. The constellation diagram of QPSK signal is shown in Fig.6. The constellation diagram shows the phase angle and amplitude of signal for different symbols. In diagram of Fig.5 the phase angles are 450, 1350, 2250 and 3150 for “00”, “01”, “11” and “10” respectively. The one bit change per symbol or 900 phase shift per symbol. The basic block diagram of QPSK modulation is shown in Fig.7. It consists of two binary phase shift keying (BPSK) modulator, serial to parallel converter, oscillator and 900 phase shift. The binary bits of information signal are separated to I bits and Q bits by serial to parallel converter at input modulator. QPSK signal of binary data is added to modulated signal over I and Q channels [8],[9],[10]. The output from both modulators is added by summer amplifier, which result is QPSK modulated signal for QPSK modulator. Basic block diagram QPSK demodulator is shown in Fig.8. The digital modulated signal (QPSK) is fed to the demodulator. In coherent detection technique, receiver is suppressed carrier signal with involves several performance consideration. In demodulator received signal is multiplied by reference frequency generators. Multipliers extracts in phase (I) and quadrature phase (Q) information streams, which are low pass filtered and fed to corresponding of bit synchronizer and signal conditioner NRZ converter block.

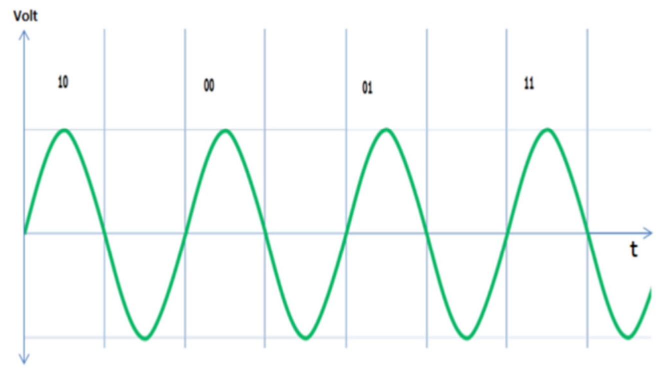

Fig.5. Output Waveform of QPSK Modulation

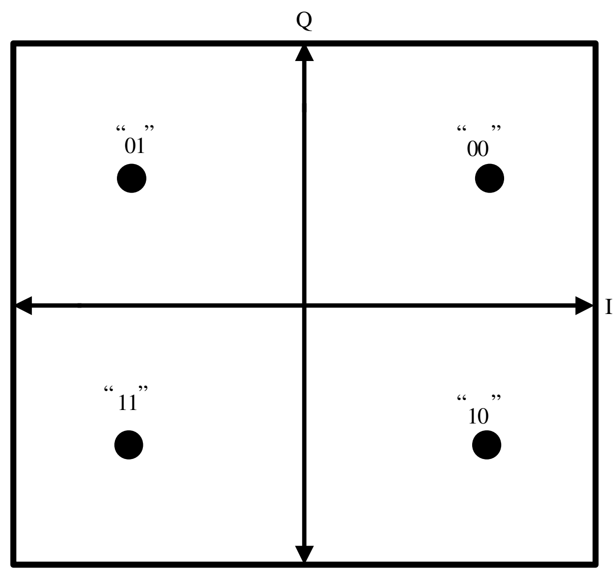

Fig.6. Constellation Diagram of QPSK

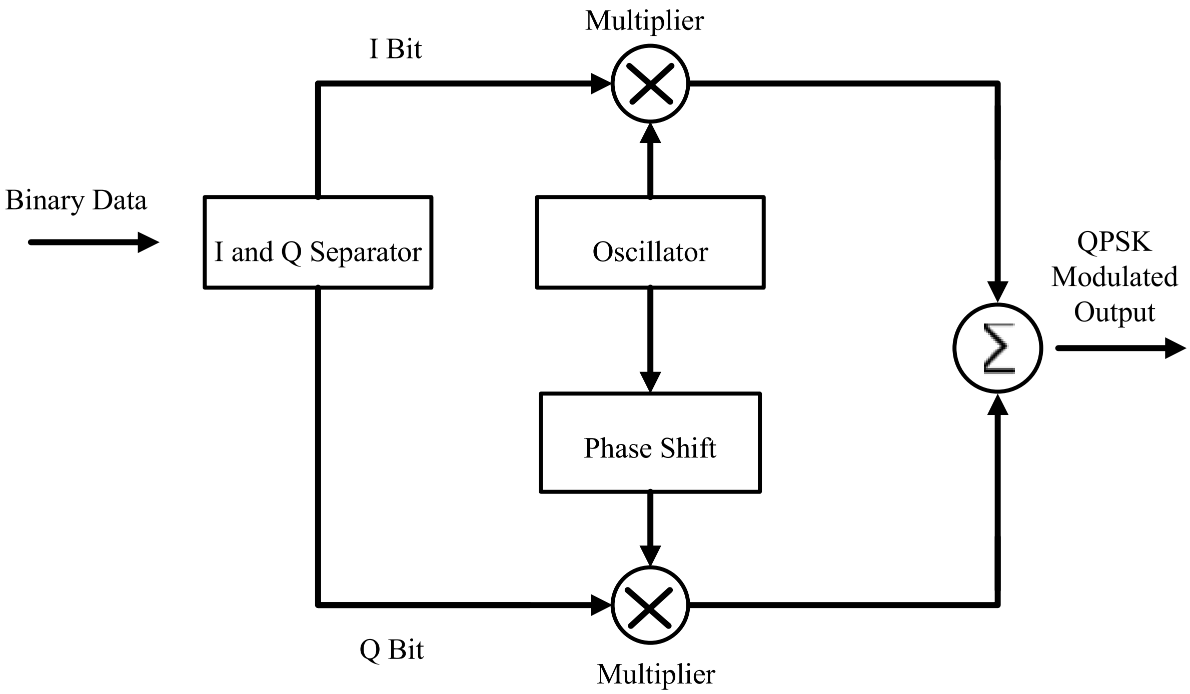

Fig.7. Block Diagram of QPSK Modulator

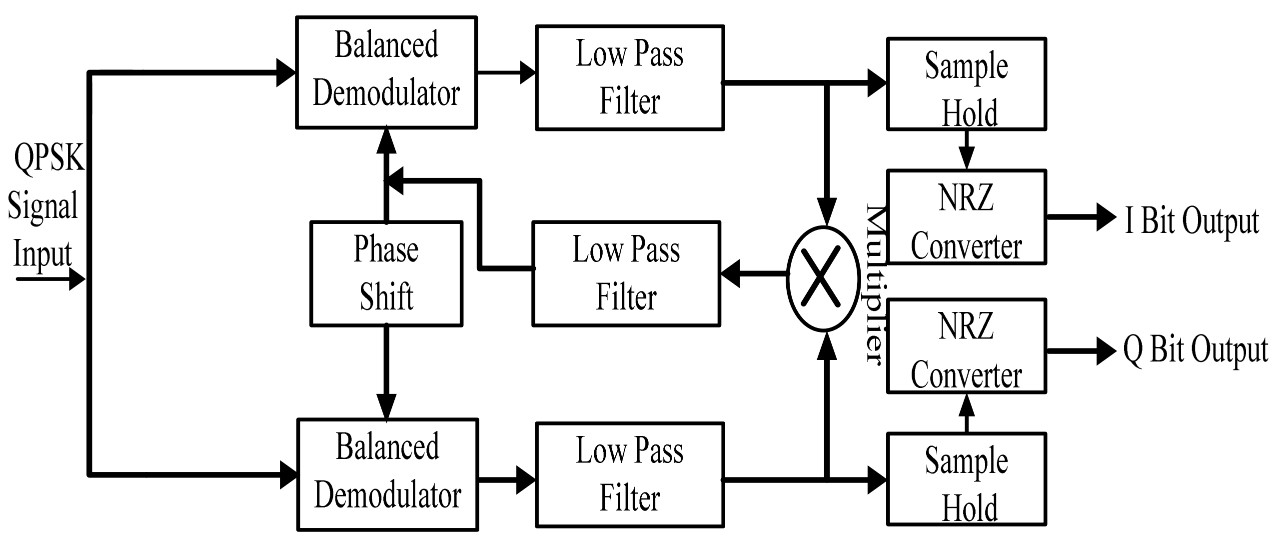

Fig.8. Block Diagram of QPSK Demodulator

IV. Simulation Result of the Proposed Model:

The simplified block diagram of PLC network with QPSK modem for smart micro grid is shown in Fig.9. The power measurement information of smart meter is supplied to modulator part of QPSK modem and that signal feed to distribution line by coupling circuit is shown in Fig.9. Distribution line is depicted for each phase with fixed line impedance parameters. The simulation diagram in Simulink of proposed model with QPSK modem is shown in Fig10. For simulation in multi-path with multiple data propagation purpose, we have considered three Bernoulli Binary generator block tools box as a sources of digital signal of three smart meters. In PLC process is analyzed in two ways one of them is energy analysis and other one is communication analysis . The three input of modulating data in this study are selected as the output power information of three smart meters. Modulated I signal and Q signal are added at output modulator. The simulation results of QPSK modulator are shown in Fig.11. The modulated signal is given as input of QPSK demodulator and the demodulated signal is similar to that of the input digital. Demodulated output is recovered from I and Q channel output at demodulation side. The simulation results of QPSK demodulator are shown in Fig.12.

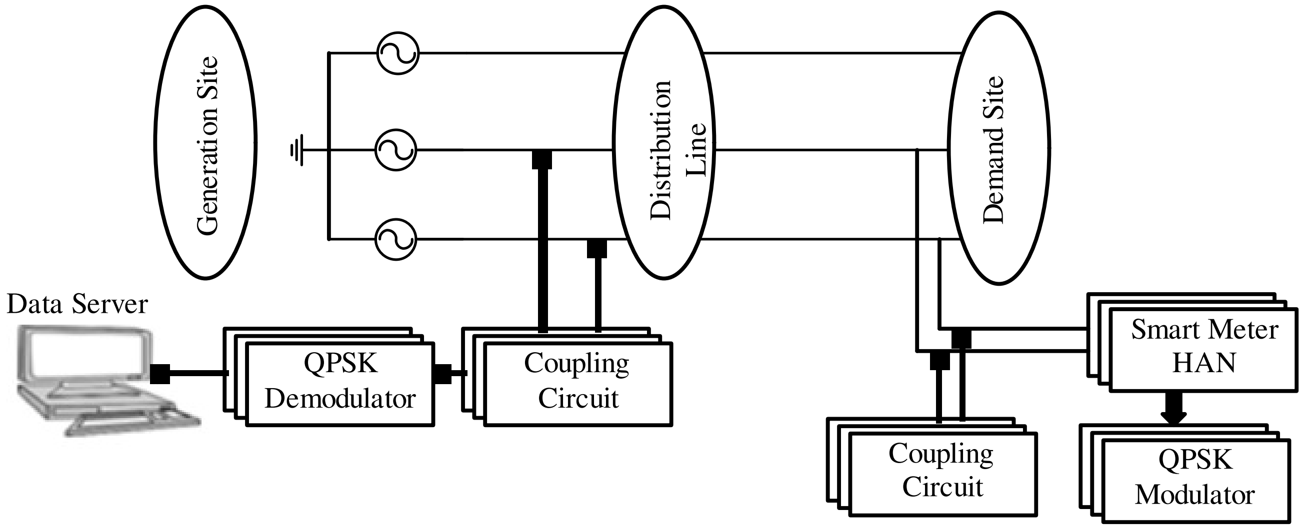

Fig.9. Simplified Diagram of PLC Network with QPSK Modem For Smart Micro-Grid

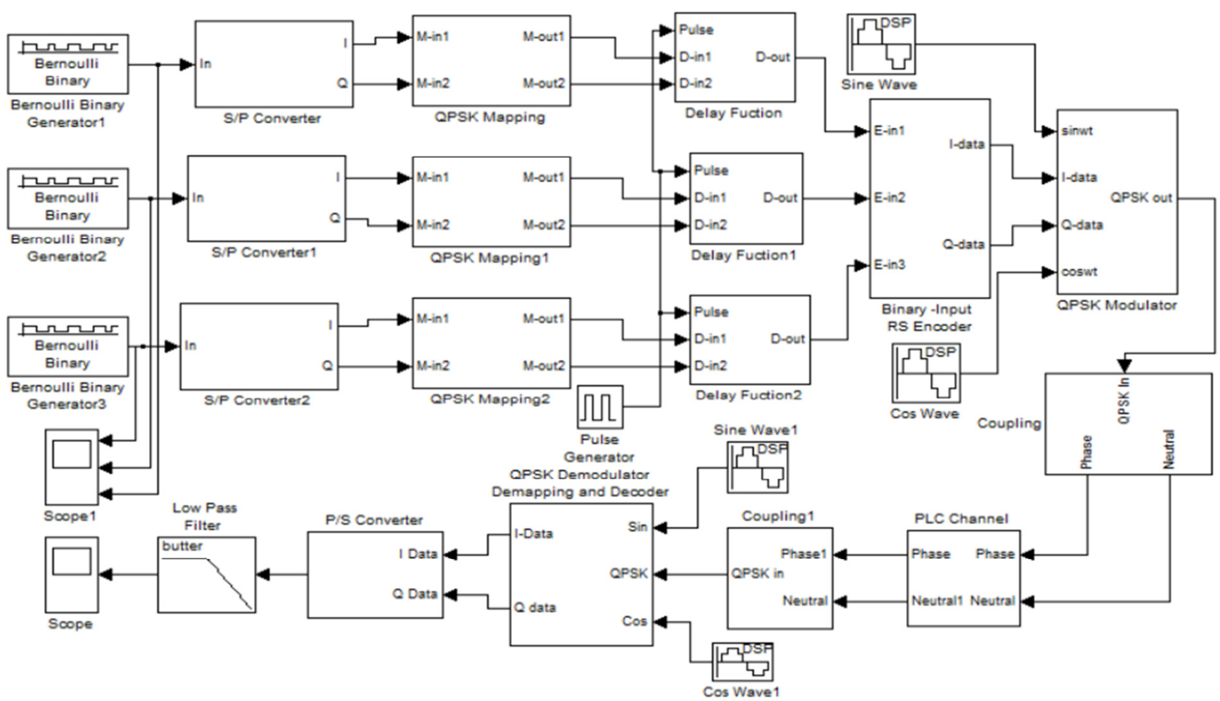

Fig.10. QPSK Modem with PLC Channel for Data Propagation in Simulink

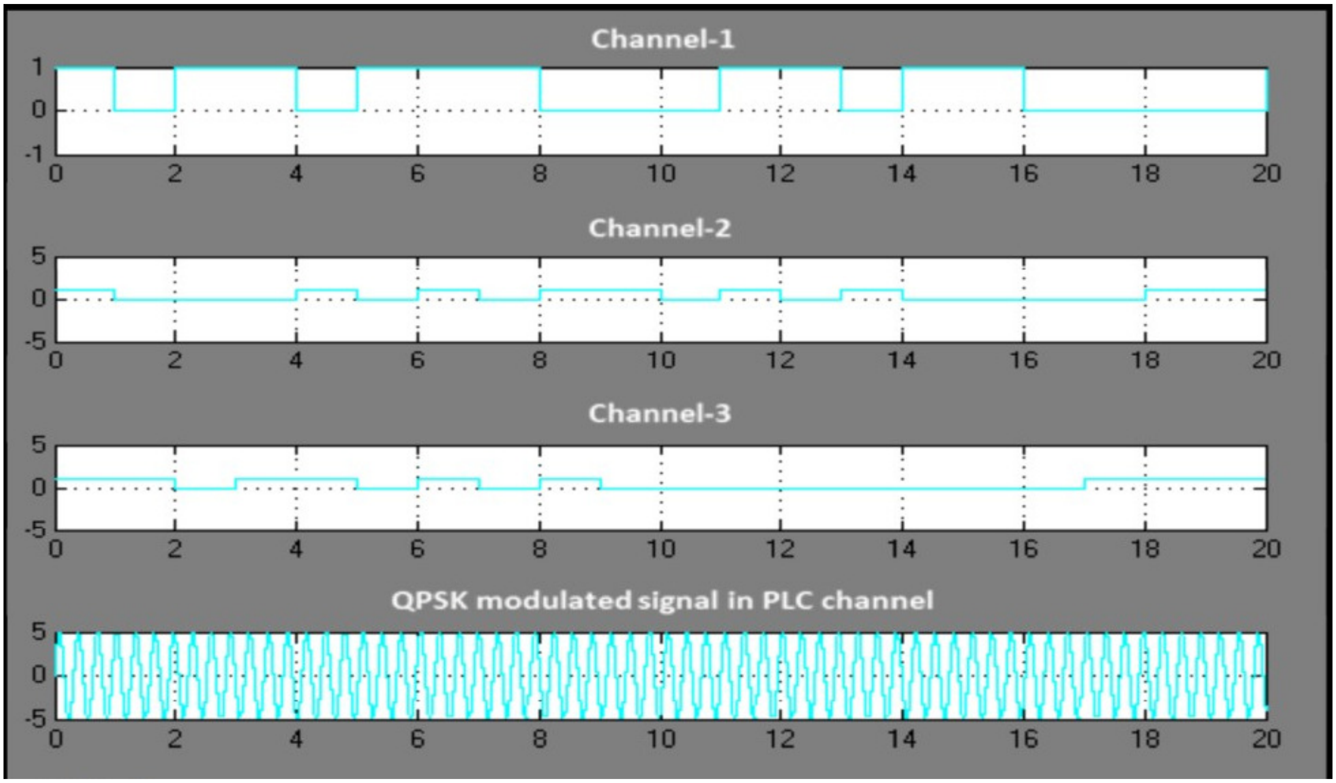

Fig.11. Simulation Result SK Modulator with PLC

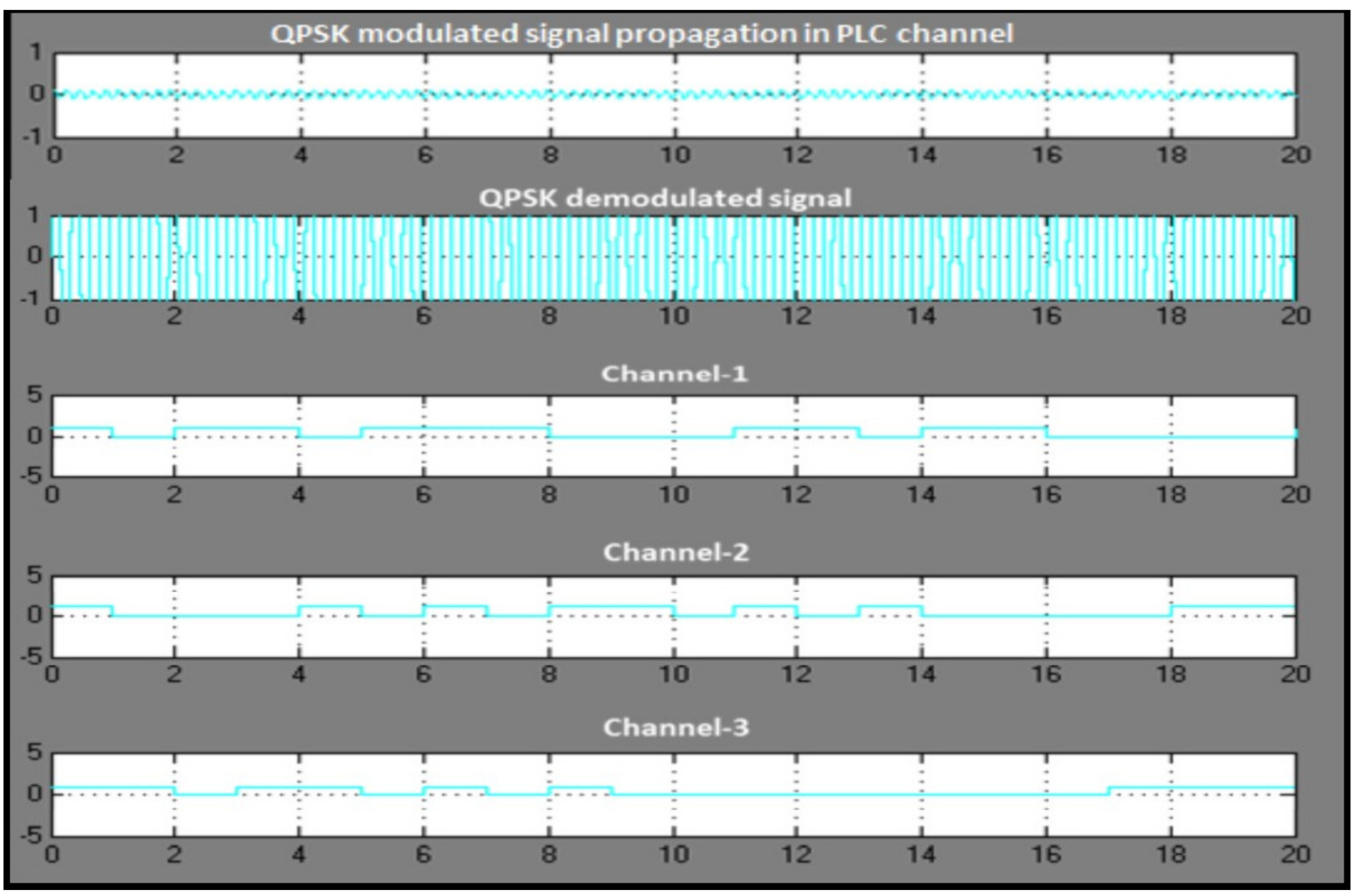

Fig.12. Simulation Result QPSK Demodulator with PLC

V. CONCLUSION:

The QPSK system focuses on transmitting and receiving the measure data of multiple smart meters in smart micro-grid system by using power linecommunication. The PLC part of study is based on modulation and demodulation system through the AC power line with coupling. The present QPSK modem is simple, low cost and able to control the data transmission for smart micro-grid. It can be an excellent, cost effective and also a reliable solution to mitigation the existing power crisis if properly implements this proposed model.

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