Domestic Implementation using X-10 Protocol Controlled by PLC

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ABSTRACT

Power lines carry energy to the appliances. The aesthetics of PLC (Power Line Communication) is that the data transmission is carried out without inserting any more cables, using a low-end but robust technology known as X-10 protocol. Nowadays the idea of intelligent homes is becoming an important feature. By making full use of X-10 technology, sending and receiving data to the appliances which are under our control by interfacing with the 220V power line and modulating our data on 120 KHz carrier burst. In this research work, we added the dimension of controlling home with the help of PLC using serial port communication i.e. by sitting anywhere we can manage the status of appliances along with attaining the temperature, light intensity, voltage and current control.

Keywords: *Domestics, Home plug, Intelligent Power Networking, PLC, Smart Home*

1. INTRODUCTION

Home automation is a step to digital housing. In this paper the discussion take place on home automation using power line communication (PLC). By means of PLC, data can be sent and received by already existing power cables. For data transmission we have used trans-receiver. Framing is used for coding in which instruction is placed between start and stop bits. In Character oriented transmission data is packed between start and stop bit.

Start bit is always low and is always one while stop bit can be two or more bits and are always high. Zero crossing detector plays important role in the circuit as it detects the point in AC signal where command signals are to be sent. In buildings different types of wiring is present. Normally to avoid any problem we are using main 220V supply for transmission of our data.

A personal computer is used in the network to control all the instructions. To avoid complexity we have used simplex transmission and power line coupling circuit is used for interfacing. FSK modulation is used by this circuit to meet high frequency need for interfacing with 220V AC signal. LDR and different other sensors are used for measuring temperature, voltage and current. PLC can be used in buildings, hospitals, in green houses and in places where monitoring is needed.

In PLC, there is no need of extra wiring rather preinstalled electric wires are used. This is the main advantage which captivates the researchers to work on PLC. Anything which is connected to the sockets in home using PLC is the part of the network and can be controlled to the desired level. One more upper head of using this network is the availability of many access points in one room as there are many sockets in each room. However noise can occur in PLC. According to power lines are connected to a transformer for supplying power however interference between signals can happen that can cause problem in communication [1]. It is discussed that narrowband noise fluctuates with day and night times [2]. According to asynchronous impulsive

noise causes fluctuation in amplitude, time and pulse width [2]. Frequency response of

PLC is different in different buildings because of difference in wiring, structure and difference in machinery connected to the network. Thus it needs monitoring and controlling. In data attenuation can occur because of various elements connected to the circuit [3]. To retain signal strength repeaters should be used which can increase the cost. Security of the network is not that much satisfactory but research work is `under process to improve it.

It is concluded that first generation PLC was able to transfer 14Mbs theoretically and this rate decreases to 10Mbs practically due to error correction and remittance caused by noise [2]. Now due to effective technologies and reliable research current innovative work shows that by using PLC that this speed can be improved to 100Mbs theoretically and 60Mbs practically [4]. Time delay in current PLC systems is very low almost up to 10 ms per next command.

2. BACKGROUND

Power Line Communication systems are also referred as demotic, Smart Home Systems or Ambient Intelligence Systems [5]. These systems will permit the controlling and monitoring of the appliances. From the many past years there has been concentration on this technology. Different techniques have been used for communication such as a ZigBee Remote control, Remote Access Device, Wi-Fi Remote Control, SMS Based Home Automation System and Home automation system using PLC.

One of the predominant applications of Bluetooth is home automation. Bluetooth technology has the aptness of transmitting the voice at half-duplex rates up to 1Mbps and data between the transportable and fixed electronic system with the non-appearance of cables but the disadvantage is incurring a access delay [6]. For the monitoring and controlling of the devices an economical and unchallenging system is to use a remote called zigbee

remote control. Instructions from the remote are dispatched to the destination device. In this method, there is a requirement of mobile which have Wi-Fi and J2ME for help in accessing and controlling respectively [7]. In SMS based home automation, GSM has many characteristics like it uses mobile network and battery power so it is secured from internet hackers which may muddle our home automation, but the drawback includes system running cost [8].

X-10 is protocol which consign signal over 120V AC wiring [9]. Digital information is represented by 120 kHz bursts timed with power line zero crossing. X-10 technology is used along with the microcontroller (PIC16F877A) for creating a home automation environment. The use of this microcontroller is because of its versatility, its flash program memory and data EEPROM.

From the above different methods discussed, the proposed method meliorates in a way because home automation using Power line communication is cost effective. Bluetooth has an issue of delay, mobile is required for Wi-Fi method along with the matter of signal distortion, SMS based are extortionate. So we are manipulating power line for our communication purpose. It will reduce the system cost and can control the devices with the assistance of personal computer by sending data over power lines.

3. METHODOLOGY

X-10 home automation is also known as X-10 protocol. X-10 protocol is a technique for home automation devices interaction. Power line is being deployed for the purpose of signaling as well as control. It is well known because it can be easily installed using pre-existing cables rather configuring new wiring system [10]. X-10 is the most promising protocol system and it is budget friendly. It permits the users to transfer (transmit) signals to homes and offices across power line wiring.

X-10 is not a complicated network. X-10 transmissions are harmonized to the zero crossing point of the AC power line. The design intent is to transmit alongside to the zero crossing point but from [11] should be within range of 200 microseconds. The delay might be 50 microseconds in between signal envelope input and 120 KHz output bursts.

X-10 communicates with trans-receiver, sends signals over the power line wiring as well as receives the

signal. Digital data sends between X-10 devices by using household electrical wiring [12]. The digital data is encoded onto a 120 kHz carrier that is transmitted like bursts during the zero crossings of the 50 Hz AC alternating current waveform. At each zero crossing, one bit is transmitted. A controller sends a command and address in the form of digital data to a controlled device and scrutinizes said devices. The status of advanced devices should simply exhibit voltage dimming level, on/off and sensor status. The device is more often plugged in the same place where home appliances are inserted. Basic configuration of PLC with X-10 is shown in Fig. 1.
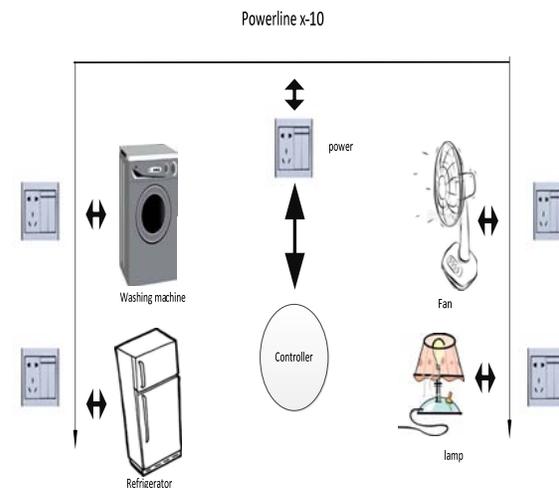

Fig 1: Basic configuration of PLC with X-10

4. HARDWARE DESIGN

The home automation PLC system major components are trans-receiver and power line module. Home owner can control the electrical load by utilizing X-10 protocol. This technology demands PLC trans-receiver switch, where the transmitter must also be included into the system to control receiver [13]. Replace this hardware mechanical switches and electrical outlet or receivers plug into main electrical outlet.

In local houses, X-10 protocol control system transports signals by utilizing the 220V power line in order to provide remote control to a particular address. Generally a trans-receiver is set to send the common address and the receiver aspires it to control. The complete flowchart of hardware design is shown in Fig. 2.

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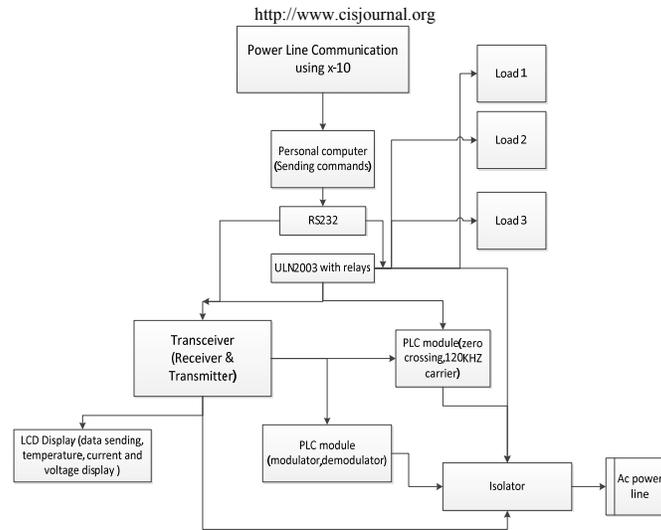
Fig 2: Flow of hardware section

Devices controlled by master slave or centralized unit is personal computer. This centralized unit sends commands to serial port (MAX232) through software which controls all on/off functionality of devices. Serial communication utilization is based on UART protocol (Universal asynchronous receiver-transmitter) for networking purpose on power line channel. Isolator is like a switching device which produces break in the connection that will bear the voltage breakdown. It just acts like a circuit protector to safe the whole circuitry from direct 220 V through 1:1 adjustment.

Overall system endorse RS232 serial interface for maintenance and configuration. Microcontroller comes with only one serial interface [14]. So, it will be connected with user interface (laptop or pc linking with serial interface) for communication [15]. The serial interface is pointed blank linked with terminal PC serial port terminal software Hyper Terminal to requisite for communicating with the system. The connections of isolator with Max232 and module are shown in Fig. 3.
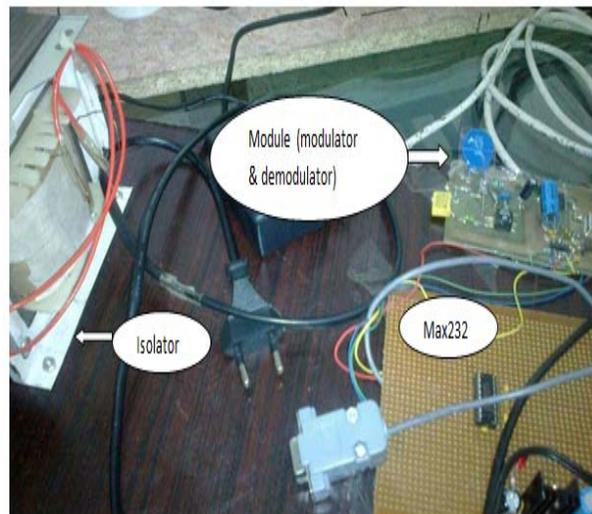
Fig 3: Isolator with Max232 & module

UART interface is the basic source to connect the nodes with personal computers by debugging the source codes and checking the nodes continuously. The whole process shown in Fig. 4.
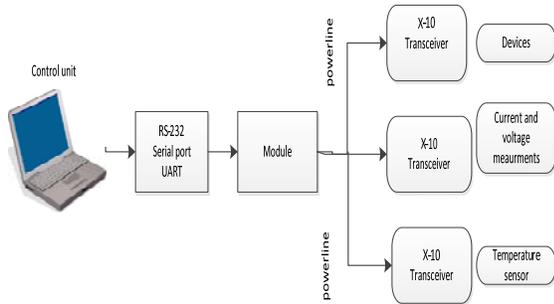
Fig 4: Architecture of the system

Asynchronous serial data communication is commonly used for transmissions. In asynchronous technique, data is placed between start and stop bits called as framing. For asynchronous communication in data framing, the data, like ASCII characters, are bind between a start and stop bit. The start bit always contain 1 bit and the stop bit can be one or two bits. The start and stop bits are 0 and 1 (0-low, 1-high) respectively.

The signal is carried by high frequency carrier because it cannot flow through power transformer across the multiphase system [16]. The zero crossing of voltage waveform is timed to coincide by signal.

Every node of X-10 system receives signal from zero crossing point which is then synchronized with X-10 transmission. To identify the signals transmitted by controller, zero crossing detector is utilized. The receiver searches the signal of zero crossing during 0.6 microseconds. Transmission synchronized with zero crossing is shown in Fig. 5.
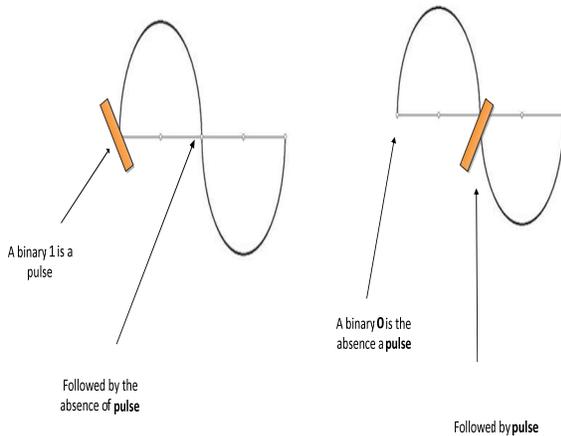

Fig 5: Transmission synchronized with zero crossing

In Power line communication all the data transmission takes place with the help of zero crossing. Use AC power lines so everything will be discussed in terms of AC supply. The zero crossing points are the points on the AC sinusoidal wave where the value of

voltage is 0V. All the data that is conveyed while using X-10 is done with zero crossing detector.

The relay is actually electromechanical device that start working through electrical current. Relay is like a remote control which is using to control many applications. Here no. of relays used to control the on/off function of the different devices. For example by using software named as Hyper Terminal, house code from A to P is sent which is shown on LCD then sends the device code that actuate the relay of required device.

ULN2003 is high voltage & current Darlington array. It is use to operate the load through relays which are connected to IC ULN2003. Connection with relay is shown in Fig. 6.
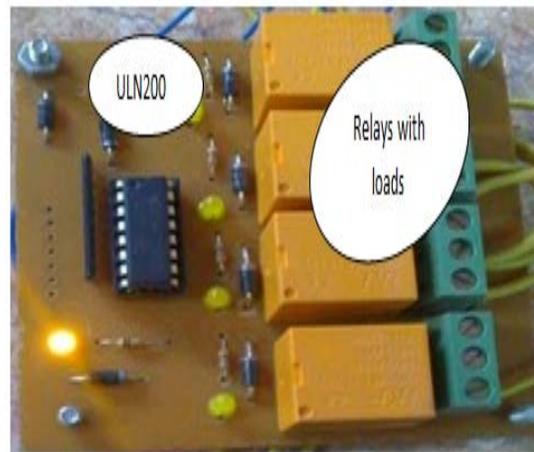
Fig 6: Relays with Max232 controlling devices

The transceiver is the vital feature of this research work. It has the ability of hearing all the incoming and outgoing instructions coming and represents those instructions as an output. In fact, trans-receiver is that portion of which sends and receive data and also displays our required outcome. .   Discussing the functionality of trans-receiver, a step down transformer is used which step downs the coming 220V form power line to 12V, as it is imperative because of the fact that our components cannot bear such high voltage. Latterly this 12V is supplied to our supply section; the supply section consists of DB107 which in its internal configuration is a bridge circuit hence it produces a pulsating DC. The capacitors remove all the spikes and perform the filtering action. This output from capacitors flow into the voltage regulator IC 7805 which is the heart of the supply section, the circuitry discussed before was just to support the voltage regulating function. The voltage regulator converts the incoming voltage into some low voltage value which is further purified with capacitors and current limiting resistors. The final outcome of this is 5V which is necessary to drive our microcontroller and all other components. Power supply connection is shown in Fig. 7.
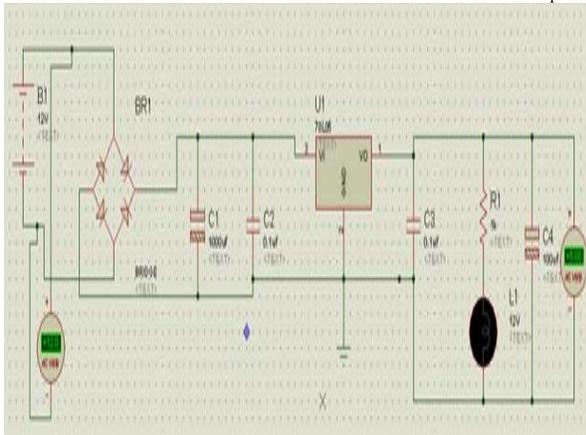
Fig 7: Power supply simulation

The microcontroller chosen for all the communication is PIC16f877A because of its dynamic features. Its pin numbers 11 and 32 are directly supplied 5V and pin numbers 12 and 31 are ground for activation purpose. The microcontroller requires a clock for its working that clock is provided by a 4MHz crystal, not any other value of crystal is being used because we have to consider our need and compatibility with this research work. Fig. 8 shows the output of trans-receiver circuit after final connections with microcontroller.

Fig 8: Output of Trans-receiver circuit

A 4MHz crystal operates at 5V and draws a current of 1.8mA. The crystal produces clock in PWM mode to derive the microcontroller. Time period of PWM is prescribed by writing into PR2 register of microcontroller and hence it is given by:

PWM period = [(PR2) + 1] * 4 *TOSC *(TMR2 pre scalar value)

PR2=41H, TOSC=4MHz, TMR2=1

Also, PWM frequency is defined as:

F =1 / [PWM period].

Now we are moving towards our output so next we have a potential transformer (PT), it is capable of measuring three phase voltage from the power line and also capable of handling high voltage along with that we have a current transformer (CT) which measures the current change whenever a load is connected. The sole purpose of using PT and CT is to demonstrate the voltage and current fluctuations when encountered the load.

In this research work we have used LM35 i.e. a temperature sensor. A phenomenon is deployed which we have used to display the temperature on LCD. All the voltage and current fluctuations along with temperature of the room will be displayed using LCD JHD16*2. The overall outcome of research work is shown in Fig. 9.
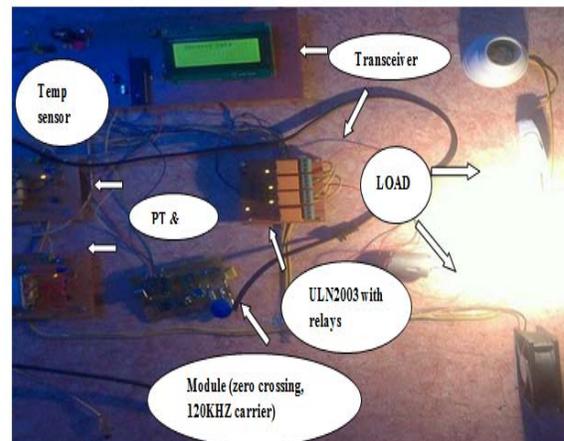
Fig 9: Overall display of Research work & it's output

The PLC module is brain of PLC circuit which is based on three important circuitries. First is Zero crossing detector, second is 120 KHz carrier generator and third is a Modulator and a Demodulator which modulates the incoming data instructions onto 50Hz frequency and demodulates all those modulated data and transfers it to the above hardware for displaying it physically. The module also performs the bit synchronization function in order to align the functions of the transceiver. Additionally it also performs the bit error removal phenomena.

A zero crossing detector is achieved by directly applying 220V to V250LA4P which is a surge suppressor. It is always directly exposed to 220V main ac wire so that it can remove the incoming spikes. It can bear 360J of energy .The resistors connected next to it are connected to limit the flow of current. The opto-coupler transfers the data from one part of the circuit to another without any direct contact between them. The BJT is initiated at 5V+ and it amplifies the output of opto-coupler which is provided to feed through along with capacitors which performs the filtering action. Fig. 10 shows zero crossing simulation of the circuit.

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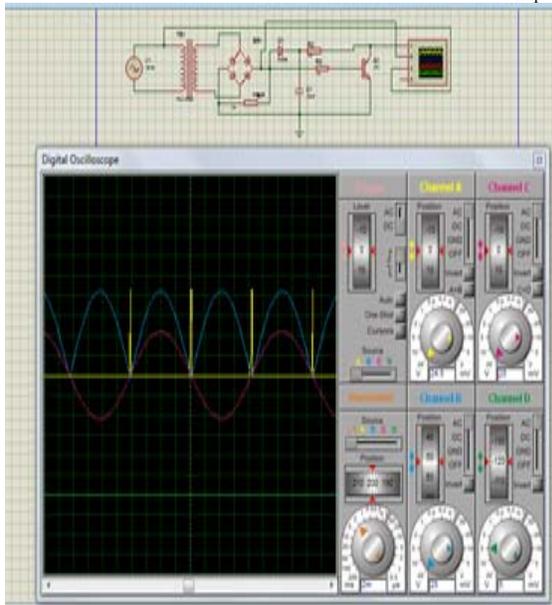
Fig 10: Zero crossing simulation

Now the capacitor C9 and inductor L1 combines and become LC band pass filter to allow certain frequencies to pass through it and rejecting others. The 78250MC is a convertor transformer which provides the isolation and interfacing with RS232. R1, L2 and C5 combine becoming RLC circuit to provide oscillations.

The TD5051A consists of ROM, a logic control, an A/D convertor and D/A convertor which internally modulates and demodulates the incoming and outgoing data respectively with the help of above components. Together 78250MC and TD5051A is also responsible for creating 120 KHz carrier generator. For this purpose, a 8MHz crystal is used to provide the clock but in reality there is always an edge between theoretical calculation and practical outcome. Practically a 7.87MHz crystal is chosen and 115 KHz signal is generated by utilizing timer 0 and prescalar 64 of microcontroller. The calculation is as following:

F = crystal value /prescalar =7.873MHz/64 = 115 KHz

5. SOFTWARE SECTION

The idea of a smart home is always very fascinating for engineers though a lot of contributions have been made yet more has to come. However, X-10 technique is the most reliable technique because of its obvious advantages of controlling your home [8].

The data transmission is very simple utilizing the existing power cables. The data is sent on synchronizing with every zero crossing points of a sinusoidal wave modulated on the 120 KHz high frequency signal of 50Hz of power line. The bits are sent in one by one fashion. The data flows in two different circuitries; a transmitter and a receiver. The whole process is shown in Fig. 11.
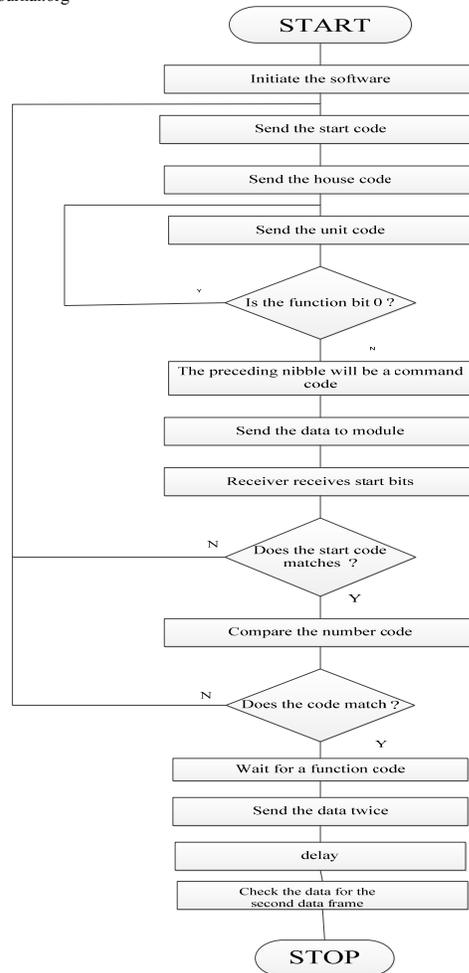
Fig 11: Flow of Software Section

First half of address of 4 bits i.e. nibble is sent. The next nibble provides the second half of the address, it is designated as "house code" and it has 16 combinations of codes ranging from A to P. Note that each combination is unique and distinguishable. The last bit of the house code is a function bit. When the function bit is 0 the previous nibble which is a house code is considered to be unit code else in the condition when its 1, for which the nibble is assumed to be a command code. Since X-10 is an economical technology it is afraid that some amount of data is lost while the transmission takes place, to overcome this all the data is send twice [12]. This all is applicable for transmitting end.

The trans-receiver starts receiving the incoming data after demodulation at the zero crossing points of the sine wave. As soon as the bits are received, bits matching operation begins for the verification. If the letter code matches exactly then the comparison of number bits start and waits for a function bit. As discussed earlier X-10 sends its code twice so that now the above procedure applies to the verification of replica of the transmitted code. After this the receiver takes rest of three cycles of sine wave, in reality it is not in rest state at this time rather

the shift registers resets itself [11]. Whenever one command or address changes to another it is separated by six clear zero crossings.
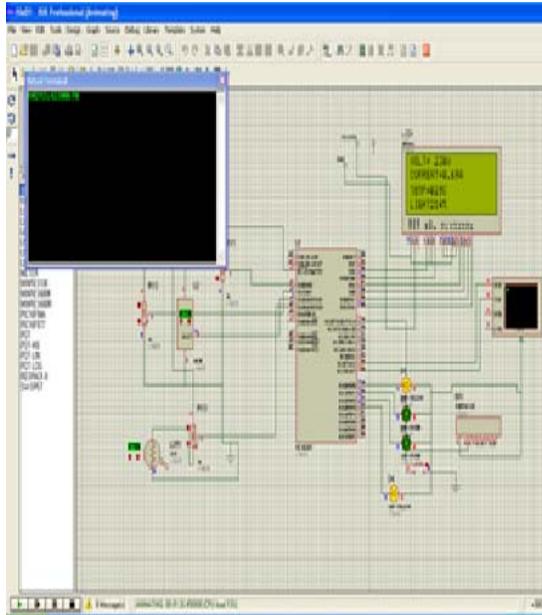

Fig 12: Output result of Software

6. CONCLUSION

This paper focuses on the novel X-10 protocol controlled by PLC (power line communication) at frequency 120 KHz with transmission range is about 300 m. It also controls 256 devices by more simple commands unlike ZigBee and Wi-Fi because both devices need local internet which have drawback of signal attenuation. To lower such type of signal attenuation we use X-10 protocol. This study has some limitations like time delay in sending the signal and the RS232 serial port disconnection but this is inexpensive project as it incorporates less distortion factor. For the exchange of data by means of power lines, a favorable method is provided which will help in controlling and monitoring called home automation using PLCs [17]. Another prominent advantage of our research work is the software Hyper-terminal that is easily available and more convenient in use. In this research paper, X-10 protocol communicates between controller and appliances over power line. This technique is used because it gives successful reduction of extra cabling with active power factor correction technique [18]. Also X-10 protocol has been devised in automation through this research work which was not accurately used in previous researches of PLC. Moreover, a module is inserted in the AC outlet which will help in interaction and communication purpose over power lines and PLC module also performs the bit error removal phenomena.

REFERENCES

[1]   H.C.; Grovè, H. M.; Hooijen, O. & Vinck, A.J. (1996). Power line Communications: an Overview, Proceedings of 4th AFRICON Conference, Vol. 2, pp. 558 - 563, 24-27 Sept. 1996

[2]   Majumder, A. & Caffery, J. (2004). Power line Communications: an overview, IEEE Potentials, Vol. 23, Issue 4, pp: 4 – 8, October-November 2004

[3]   S Hughes and D J Thorne, Broadband in-home networks, BT Technol J., pp.71-79, Vol. 16 No. 4, October 1998

[4]   Kwang Ye Lee, Jae Weon Choi, Remote-Controlled Home Automation System via Bluetooth Home Network, SICE Annual Conference in Fukui, Vol.3, pp. 2824 - 2829, August 4-6, 2003.

[5]   Khusvinder Gill, Shuang-Hua Yang, Fang Yao, Xin Lu, A ZigBee-Based Home Automation System, IEEE Transactions on Consumer Electronics, Vol. 55, No. 2, pp. 427, May 2009

[6]   Zamora-Izquierdo, M.A , Univ. of Murcia, Murcia, Spain , Santa, J. , Gómez-Skarmeta, A.F, "An Integral and Networked Home Automation Solution for Indoor Ambient Intelligence", Pervasive Computing, IEEE, Vol.9 , pp. 66 – 77, October-December 2010.

[7]   D. Valtchev, and I. Frankov, "Service Gateway Architecture for a Smart Home," IEEE Communications Magazine, Vol. 40, No. 4, pp. 126-132, 2002.

[8]   Zhang Yuejun, Wu Mingguang, "The Study and Development on Intelligent Lighting System Based on X-10 Protocol", China Illuminating Engineering Journal, Vol. 15 No. 1, pp.22-26, March 2004.

[9]   A.J. Bernheim Brush, Bongshin Lee, Ratul Mahajan, Sharad Agarwal, Stefan Saroiu, and Colin Dixon, "Home Automation in the Wild: Challenges and Opportunities", CHI 2011, Vancouver, BC, Canada, May 7–12, 2011

[10]   D. Valtchev, and I. Frankov, "Service Gateway Architecture for a Smart Home," IEEE Communications Magazine, Vol. 40, No. 4, pp. 126-132, 2002.

[11]   Sheikh Izzal Azid, Sushil Kumar, "Analysis and Performance of a Low Cost SMS Based Home Security System International Journal of Smart Home Vol. 5, No. 3, pp. 15, July, 2011.

[12]   Zhang Yuejun, Wu Mingguang, "The Study and Development on Intelligent Lighting System Based on X-10 Protocol, "China Illuminating Engineering Journal, Vol. 15 No. 1, pp. 22-26, March 2004.

[13] Su Xifeng, "Application Technology of a Coding and Decoding Circuit," Journal of Yellow River Conservancy Technical Institute, Vol. 15 No.2, pp. 45-47, April 2003.

[14] Lin, Y.J.; Latchman, H. A. & Lee, M. (2002). A power line communication network infrastructure for the smart home, IEEE Wireless Communications, Vol.9, pp. 104-111, December 2002

[15] Lin, Y. Latchman, A. & Newman, R. E. (2003). A comparative performance study of wireless and power line networks, IEEE Communications Magazine, Vol. 41, Issue 4, pp. 54 – 63, April 2003

[16] Ferreira, H.C.; Grovè, H. M.; Hooijen, O. & Vinck, A.J. (1996). Power line Communications: an Overview, Proceedings of 4th AFRICON Conference, Vol .2, pp. 558 - 563, 24-27 September 1996

[17] Soo Hwan Choi, Byung Kug Kim, Jinwoo Park, Chul Hee Kang, Doo Seop Eom, "An Implementation of Wireless Sensor Network", IEEE Transactions on Consumer Electronics, Vol. 50, pp. 1, 2004.

[18] M.M. Jovanovic and Y. Jang, "State-of-the-art, single-phase, active power- factor correction techniques for high-power applications—An overview," IEEE Trans. Ind. Electron., Vol. 52, no. 3, pp. 701–708, June 2005.