DATA TRANSFER OVER A LOW VOLTAGE POWER LINE FOR DATA ACQUISITION AND MONITORING OF ELECTRICAL APPLIANCES

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ABSTRACT

This article presents the design and implementation of a data communication system over a low voltage power line, meant primarily for applications of data acquisition from sites and monitoring of electrical appliances at the sites. The hardware developed, the interfacing required and the software used for implementation of the protocol are addressed. The developed system has been tested and results in a noise free and noisy power line system are reported. This paper reviews the previous studies on the power line as a transmission medium, proposes and evaluates the noble protocol for such applications.

Keywords: communication, protocol. data coupling, interfacing.

1 INTRODUCTION

The in-building low voltage power distribution wiring is used as data communication medium for transmission of analog and digital data in this work. As data networks have gone from being an experimental technology to becoming a key tool for business and entertainment by companies and homes worldwide, so there has been a flurry of research activities by researchers on using power line wirings for network instead of using dedicated network cables [1]. Power line communication has been thoroughly elaborated in terms of its potential for being as a medium for broadband networks applications [2]. Some interests have focused on the characterization of power line as a channel, thus showing what changes in terms of phase and strength a signal undergoes after passing through a power line [3, 4].

This paper gives a complete structure of the power line communication for use in controlling electrical appliances and acquiring data from data sources. The coupling circuits are developed and their frequency selectivity is tested and simulated extensively. MODEM chips are used on each end to help mount and decouple the signals onto the power line and the signals after and before their transmission are studied through a powerful oscilloscope. A Graphical User Interface (GUI) based on Visual Basic is developed and a protocol is implemented in embedded C for the transmission of data packets. The protocol works for a reliable transmission of control and data packets. After having done with all, the modulated signal is injected into line and tapped at the other receiving point demodulated and processes accordingly. In overall, the initial work on monitoring, control and data acquisition based on the power line data communication has operational as desired.

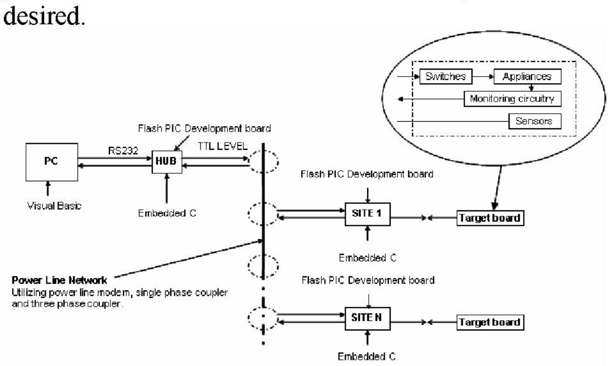

Figure 1 Block Diagram of the Power Line Data Communication System

2 SYSTEM DESCRIPTION

Figure 1 depicts the overall block diagram of the power line data communication (PLDC) system. A personal computer is used as an input console to acquire data from, monitor and control the appliances connected to respective sites. The computer is interfaced to a low voltage power line through coupler and modem circuits. The couplers function to isolate the electronic components from the power line as well pass on the frequency components allowable under the modem band. A similarly designed board at the destination of the sites decouples the data signals for recognition of the address bits. If recognized then a given site is through for communication with the hub (master) in order to acquire data (or disseminate instruction) bits for proper action by the board at the site

2.1 Signal on Line

The data signals are modulated by the power line MODEM prior to mounting them on to the power line through single phase coupler (Figure 2).

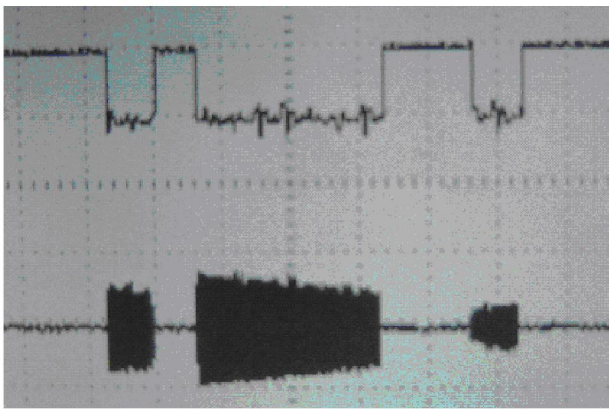

Figure 2 Data Signal Before and After the Line Coupler

The signal is received by all the connected sites via the single phase coupler, which is demodulated for checking the address embedded in the data packet. The site executes the received instruction after having found a match on the address. The site is attached to the target board that is consisting of an array of LEDs to imitate electrical appliances, monitoring circuitry and potentiometers used as data sources.

The status of the appliances will be checked at the end of each control appliance operation or each site status application. The present site status will be fed into the line via the modem and the single phase coupler by the site. The signal then tapped and demodulated by the hub (master) to be relayed to the personal computer (pc). Then, the pc updates the status monitoring tab referring to the present site status received. In the data acquisition operation, the data read from the sensor will be fed onto the power line as discussed above and retrieved by the hub before being fed to the pc for display. The data in appropriate entry will be updated on receiving that signal.

2.2 Hardware Schematic of Power Line Modem And Coupler

The schematic diagram for the power line modem, single phase coupler and the power supply is shown in Figure 3 with a PCB in Figure 4. The TDA5051A power line modem used in this work uses the amplitude shift keying (ASK) principle for modulation of a signal where the logic ‘0’ is represented by the burst of signal with frequency of 125 kHz and logic ‘1’ represented by nothing. The single phase coupler allows signal in 85 kHz up to 145 kHz frequency band, while for the inter-phase communication, a three phase coupler is designed to work in the same range.

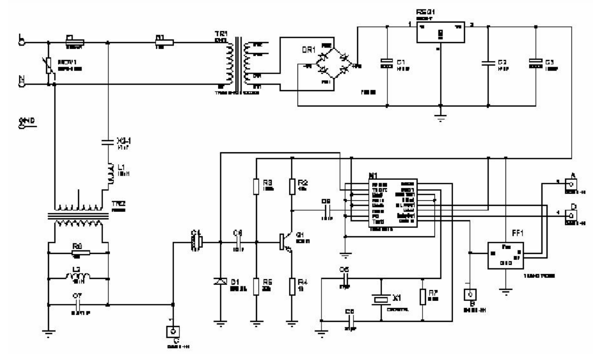

Figure 3 Power Line Modem, Coupler and Power Supply Schematic Diagram

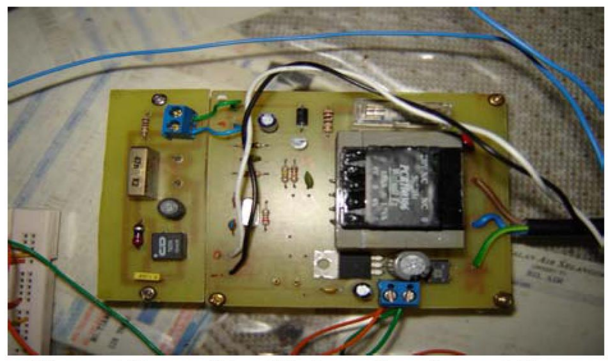

Figure 4 Power Line Modem, Coupler and Power Supply Circuitry developed in Single Printed Circuit Board

The complete hardware set for both master and site board is shown in Figure 5 and Figure 6 respectively

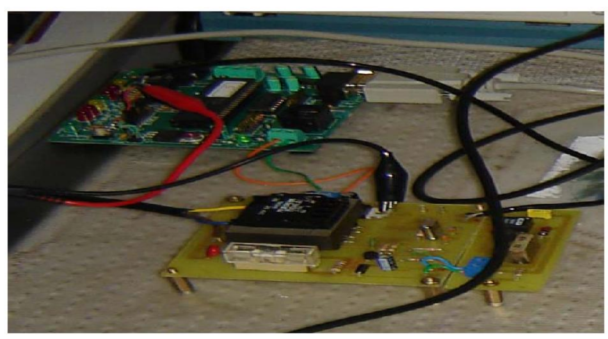

Figure 5 Complete Master Board

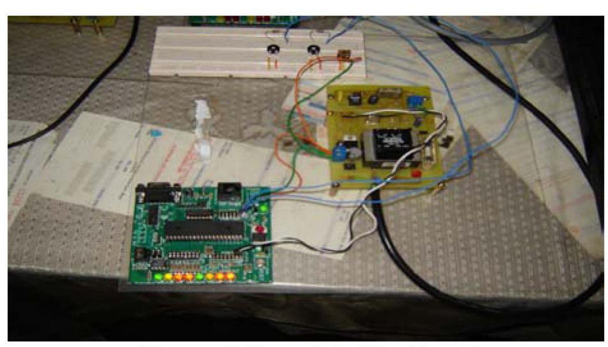

Figure 6 Complete Site Board

3 SOFTWARE AND PROTOCOL DESIGN

PIC16F877 is used as a core device on the master and site boards, which are programmed with embedded C. The serial communication between the computer and the master unit is a simple two wires connection which uses RS232 converter in between to ensure smooth communication between the two at a baud rate of 9600 b/s. A special protocol has been designed in ensuring no data collision takes place during data transmission. The communication is initialized by the computer, thus ensuring that only one way communication takes place at a time.

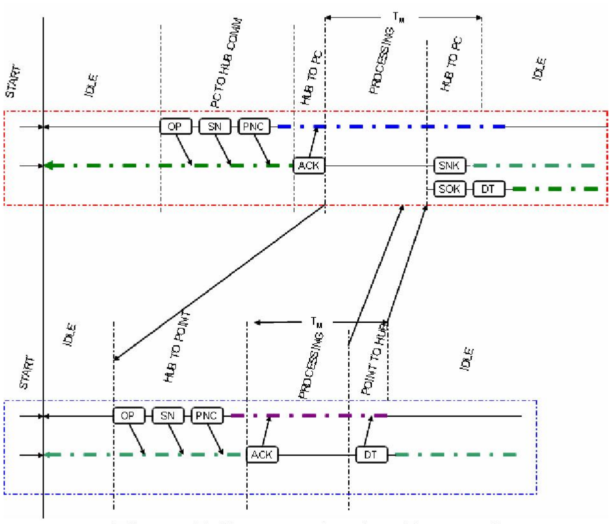

Figure 7 Communication Protocol

The PC-to-master and master-to-site protocol is implemented as depicted above, showing a pc sending three special data bytes to the master. These data bytes are op (operation), sn (site number) and pnc (point number) respectively. The hub after acknowledging to the pc, send the above signal onto the power line network for onward transmission to the sites. A given site with the embedded address responds with the corresponding action after the necessary processing. If a site, for some reason, is not available or unable to respond in a prescribed period of time, then the hub sends the pc a coded message which prompts the user through an “N/A” message. Only two sites are attached to the hub through the power line just for testing purposes.

The protocol developed enables data flow from pc to site and vice versa with reliable accuracy, and tested to work accordingly

3.1 Graphical User Interface

GUI is developed in Visual Basic enabling devices on a given site to be activated through a click of mouse (Figure 8). The activated devices are shown in the form of color change indicating their status of connectivity to the system.

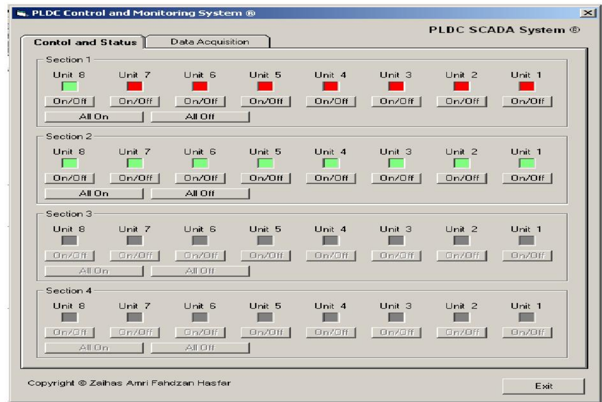

Figure 8 Control and Status Tab

Eight switch boxes are provided for independent control of the appliances that are served by each site, where through each individual device is switched on (or off) independently, or all devices simultaneously.

In the case of data acquisition, the special acquisition tab is designed (Figure 9), which enables the users to acquire the data from either of the connected data sources, one at a time. For simplicity, data from two sensors is obtained and displayed on the computer console each time the acquisition button on the tab is clicked.

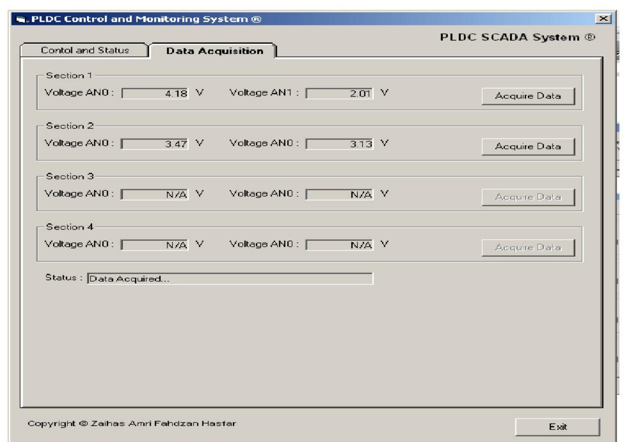

Figure 9 Data Acquisition Tab

In both data acquisition and control of appliances, once the event button is clicked, the signals containing data (or control information) are sent by the computer in data packets. The master unit relays the data packets onto the power line via the power line modem and phase coupler.

4 TESTING

Two tests are carried out to evaluate the performance of the couplers used, the power line modem, the software and protocol developed. The details of these tests are presented in the sections that follow.

4.1 Testing the Signal Transmission

The personal computer is connected to master via the RS232 (Figure 12), while the master and the sites are coupled with the power line via the modem and the single phase coupler. Once powered up, the master prompts the user to 'press any key', which sends the key's ASCII out to the site.

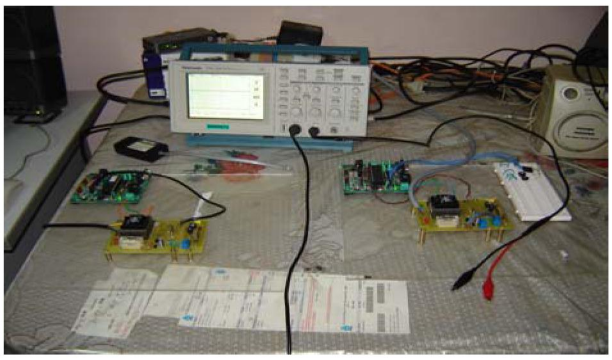

Figure 10 Experimental set up

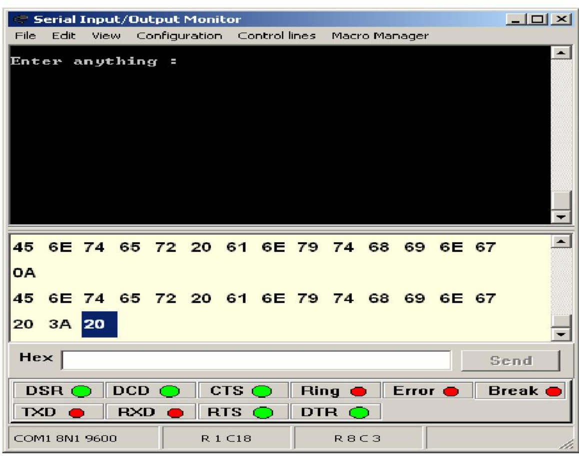

Figure 11 Serial Input Output Window (SIOW)

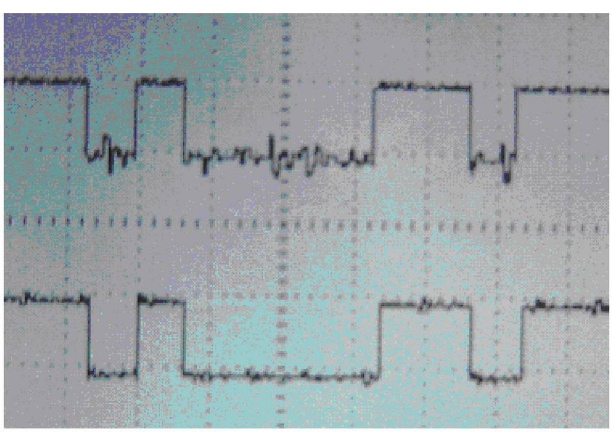

Figure 12 Above Shows Data Transmitted and Below Shows Data Received

The transmitted signal at the master and the received signal at the site were monitored on an oscilloscope (Figure 12). This depicts the successful data transmission between the master and the site. The data is successfully transmitted if the signal is properly coupled to the power line at baud rates of 300, 600, 1000, 1200 b/s. The 1600 baud rate shows partial transmission, but the transmission fails completely at the baud rate of 2000 b/s.

4.2 Testing Of Complete System

The complete system (Figure 13) has been tested as discussed in the introduction. The PC-to-hub communication is verified through the Visual Basic interface. The Visual basic programming is launched by selecting the appropriate COM port following the steps shown in Figure14 up to Figure 17. If the selected com port is not supported by the pc, then the pc prompt the error as shown in Figure 18.

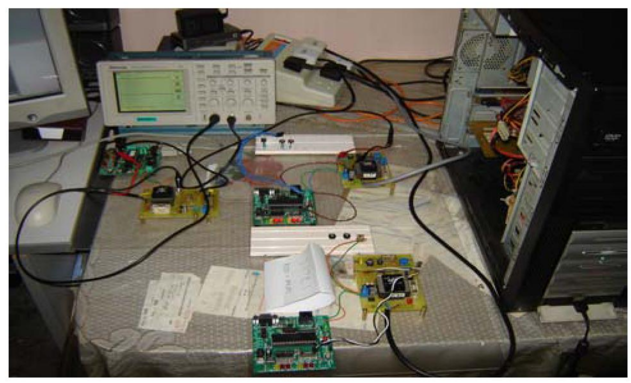

Figure 13 Experimental set up

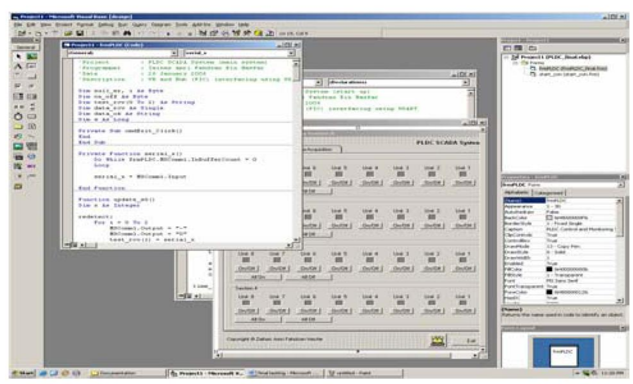

Figure 14 Visual Basic programming windows.

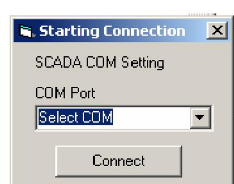

Figure 15 Start up program (choose COM)

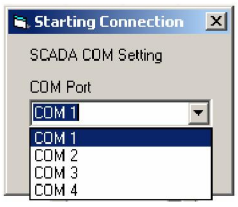

Figure 16 Combo box selection of COM

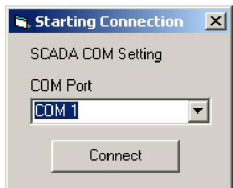

Figure 17 COM 1 Selected

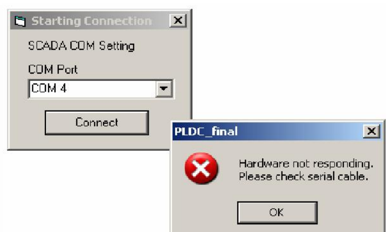

Figure 18 No Hub Detected (error occur)

When initialized, the system should be able to detect the sites and the status of the connected devices to the sites. For data acquisition testing, the hub is configured to acquire data from a potentiometer imitating as a data source sensor. The sensor reading is displayed on the pc when it is received. The potentiometer reading is varied to verify the accuracy of the data received.

5 PERFORMANCE AND RESULTS

The operating baud rate of the system in this work is reported to be at 1000 b/s, a limitation of due to dissimilarity of the rise and fall transition times of the MODEM used in this work.

The developed system works reliability within a distance of up to fifty meters. As reported, the system is unable to work appropriately if some noise generator equipment such as air conditioner is switch on, affecting the system performance.

6 CONCLUSIONS

This paper has presented the basic technical information on sending data through power-line for the purpose of low baud rate applications including monitoring and control. The applications considered in this work are controlling of electrical appliances by sending control signals from the monitoring station through the hub and occasionally reading data from the respective data sources including sensors. A Visual Basic graphical user interface is developed with features appropriate to these applications. Choosing a site on the GUI and the necessary appliances, the user can enable turning ON or OFF the intended device. Similarly, choosing a site and a relevant sensor, the user can read data for making it available on the monitoring PC. The system is tested and operated successfully, however suffering from inaccuracy due to noise generated by loads with rotating parts and served by the same power line. The protocol developed works properly and avoids any collision of data once it is on the power line. This work can be used as a stepping stone for turning ON (or OFF or dimming) of electrical appliances in multi-storey premises or of the illumination lights on highways and golf resorts without physically approaching these appliances.

7 ACKNOWLEDGEMENTS

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