Web-based Smart Home Automation: PLC-controlled Implementation

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Abstract: The most important source of motivation in continuity of technological developments is to upgrade human living standards. The technological development provides and increases human-beings' safety and comfort directly and indirectly. Developing technologies for this purpose directly affects the life standards by means of smart home systems design. It is possible to classify smart home systems into two as local and remote. In this study, a smart home automation system design was carried out by using Delta DVP28SV model PLC (Programmable Logic Controller). Smart home system can be controlled in two different ways either by any internet-connected device or an operator panel assembled on PLC. Control of the ventilation, lighting and security units in the smart home were carried out. Instantaneous states and variations of the smart home system which is feedback based are monitored and can be changed from the user interface prepared with the C# programming language. Unusual circumstances occurred in security units have been reported to the user with SMS (Short Message Service).

Keywords: Home automation; PLC; Remote control; Smart home

1 Introduction

The "smart home" concept has emerged in the early 1980's when "smart building" concepts started to be used. In those years, smart homes were designed only for user convenience [1]. "Smart homes" have smart technologies having remote or centrally controlled functions and services. In a smart home, the inhabitants' wishes and needs concerning all or some part of equipment and functionality have priority [2].

In smart house systems, the internet is also used to ensure remote control. For years, the internet has been widely used for the processes such as surfing on the pages, searching information, chatting, downloading and installation. By the rapid developments of new technologies, monitoring, controlling services have been started to be served along with internet as an instrument providing interaction with machinery and devices [3]. In smart house systems, comfort and security of houses have been enhanced, usage of energy and other resources were provided in a more rational way, and considerable savings have been achieved [4, 5, 6]. In the beginning, the "smart home" idea was aimed to raise home comfort of people who are not disabled. Nowadays, it is also convenient to satisfy personal needs of older and disabled people, to help and support those people. This application area is very important and promising in the future [1, 4]. The concept of providing proper and full control on each device and electrical equipment as well as no requirement for processes, which required manual control before, are the reasons for being under concentration.

In recent years, intelligent systems were preferred for residences, shopping malls, skyscrapers, hotels, etc. There is a large market share for intelligent building devices. Many organizations, such as MIT, Siemens, Cisco, IBM, Xerox, Microsoft, etc., have been working on this issue and these groups have set up about 20 pieces of a smart home lab. These laboratories are not a training set. Each of the buildings covers a large footprint [7, 8].

To build a superior intelligent building, there are some essential points that should be taken into consideration. In order to make the system high-qualified and successful, an experienced designer who is very suitable for environmental conditions, open to developments, and who is very well familiar with the system is needed. The term" intelligent design" includes meanings such as sustainable design, high-tech usage and user-friendly design [8].

Smart homes can be dealt with four main aspects:
- The physical structure of the building
- The system (security, air conditioning, power control)
- Services (Internet, communication)
- Management (energy, illumination, irrigation)

The physical structure of the building is important in terms of heating and natural ventilation. This feature is implemented in the project phase of the building. Engineers carry out the calculation of correct use of insulation material and the positioning of the building for energy saving in the beginnning phase of the project while drawing the project. The other three basic aspects can be applied on the foundation after the construction of the building and even for pre-made buildings [8].

In today's modern era, automation is rapidly advanced while it becomes a part completing our homes and offices [9]. Automation can be generally described as a process following pre-determined sequential steps with a very ~~a~~ little or without

any human exertion. Automation is provided with the use of various sensors suitable to observe the production processes, actuators and different techniques and devices [10].

During the design process, home automation system must be effective, easy to apply and at an affordable price. PLC is considered as an alternative to such systems. PLC, security monitoring, energy consumption management and control of machines and automatic production lines that are included in almost every field of industry automation systems in particular, are commonly used [11]. PLC is an electronic device designed to be used in the field of industry that controls a system or groups of systems through analog/digital data input/output terminals, providing general control by means of inherent functions of timing, counting, data processing, comparing, sorting, data transfer and arithmetic operations. At the same time use of PLC is very advantageous for several reasons such as being able to make changes on the software and for resuming the algorithm as the energy supplied back by saving data for a long time in the case of power failure.

The traditional teaching of engineering subjects, an appropriate combination of theory, exercises and laboratory experiments should be provided [12]. In order to gain practical skills and experience, theoretical knowledge as well as intensive training in a laboratory must be given to electrical engineering students [13]. Constructivist educators propose that processes such as knowledge or learning are initiated by the individual his or herself. Training materials are needed to be presented to student both in a convenient and attractive way [14].

Many smart home systems developed for educational purposes are available in the literature. Here are some examples designed for educational purposes; set-design for smart home education [8], a smart home lab for students [14], a tool for facilitating the teaching of the smart home [15], a laboratory experiment for teaching automation inspired by the smart home [16], automatic small-scale house for teaching home automation [17], and remote control laboratory using a greenhouse scale model [18].

In this study, a web-based software and hardware application for smart home automation system has been realized. Security (gas and smoke, motion, door control) and comfort (lighting and climate control) of the smart home is provided by means of remote control. In this study, the PLC equipment called DVP28SV of Delta company with a sufficient number of digital and analog address has been used for the storage of the required information belonging to the smart home and due to ease of application over the operator panel. On the used PLC, there is 6 digital input (DI), and 12 digital output (DQ) terminals. In addition, one analog module named DVP04AD-S having 4 analog input (AI) terminals and one Ethernet module named DVPEN01-SL have been connected to the PLC. Smart home system is controlled by both PC and operator panel called DOP-AS35THTD. The user interface is written using C # programming language.

2 The Architecture of Smart Home System

In this study, a PLC controlled smart home application which can be controlled by using computer, mobile devices and operator panels via the Internet is implemented. This application is composed of two parts, including software and hardware. General block diagram of the system is shown in Figure 1.

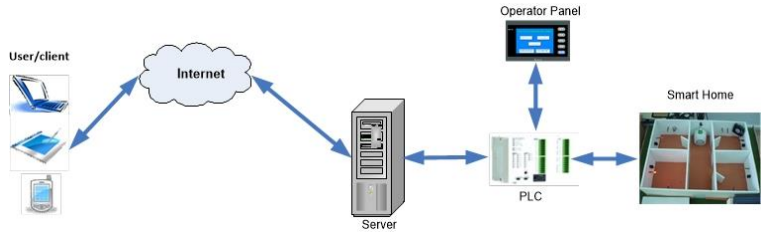

Figure 1
The block diagram of smart home system

2.1 Hardware Infrastructure

Infrastructure of the performed application of smart home hardware consists of Delta DVP28SV model PLC, DVPEN01-SL Ethernet module, DOP-AS35THTD touch operator panel, sensors, actuators and electronic circuits. In this study, 7 out of 16 digital inputs of the PLC, and 11 out of 12 digital outputs are used. Block diagram of PLC module is shown in Figure 2, while the inputs / outputs of the PLC used in the study are shown in Table 1.

It is possible to divide units controlled in the smart home system into 3 as lighting control, security control and air conditioning unit. Controls of these units are carried out by the operator panel connected to mobile devices and the PLC via the Ethernet module connected to the PLC. Via the lighting unit, living room, bedroom, kitchen and hall lights are controlled. When the system is turned on, lighting data of rooms are read and written to the database, and then transferred to the user interface so that the user can observe the current situation of rooms and changes in the state of the lights. In the energy-saving mode, thanks to the sensors, lights in unused rooms are automatically turned off.

In safety unit, gas leakage, fire, theft and door security checks have been done. When a signal is detected by gas and smoke sensors placed in the smart home, they run the alarm circuitry and information for the user is provided on the user interface. When an intruder is detected by the motion sensor placed in the hallway, pictures are taken by the camera and sent into e-mail of the user or another pre-defined address, and information is given in the user interface. With the sensor placed to the gate of the house, intrusions from the entrance door are detected and the alarm circuitry is activated.

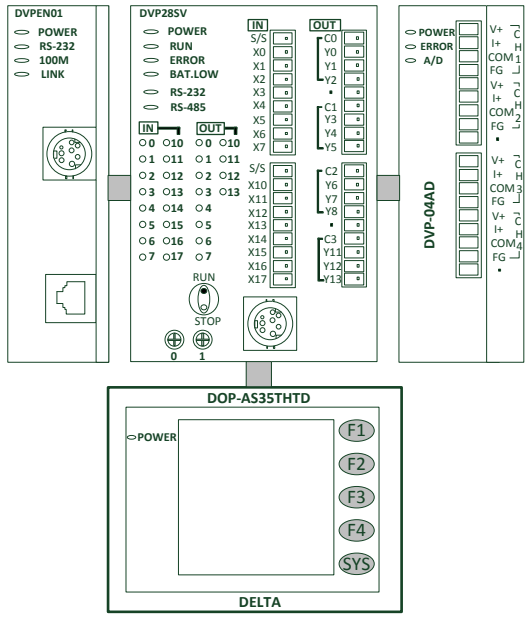

Figure 2
PLC module block diagram

Table 1
PLC Outputs and Inputs

Inputs	Tasks	Outputs	Tasks
X0	Living Room (Lighting Control)	**Y0**	Living Room (Lighting Control)
X1	Bedroom (Lighting Control)	**Y1**	Bedroom (Lighting Control)
X2	Kitchen (Lighting Control)	**Y2**	Kitchen (Lighting Control)
X3	Hall (Lighting Control)	**Y3**	Kitchen (Lighting Control)
X4	Entrance Door (Security Control)	**Y4**	Saving Mode (Lighting Control)
X5	Gas and Smoke (Security Control)	**Y5**	Alarm (Security Control)
X6	Motion Sensor (Security Control)	**Y6**	Heater (Ventilation Control)
X7	Temperature (Ventilation Control)	**Y7**	Cooler (Ventilation Control)
X9	-	**Y11**	Motion Sensor (Security Control)
X10	-	**Y12**	Gas and Smoke (Security Control)
X11	-	**Y13**	Entrance Door (Security Control)

Air-conditioning unit is a control method carried out in order to ensure the comfort of home residents. With the temperature sensor capable of measuring temperature between -55 C^0 and +150 C^0 placed on the smart home, the temperature of the house is measured in real time and transferred to the user interface. The user can set home temperature to any value. The coolant is activated when the home temperature is above the value set, and the heater is activated when it falls below it.

In order to perform controls mentioned above, active/passive settings on PLC inputs and outputs must be made.

Table 2

Equipment used in smart home system

No	Hardware
1	PC
2	Web Camera
3	Electronic circuit control cards
4	Relays
5	Supply of electronic circuit cards
6	PLC power supply
7	DVPEN01-SL Ethernet module
8	DVP28SV model PLC
9	DVP04AD-S analog module
10	Smart home prototype
11	Modem
12	DOP-AS35THTD operator board

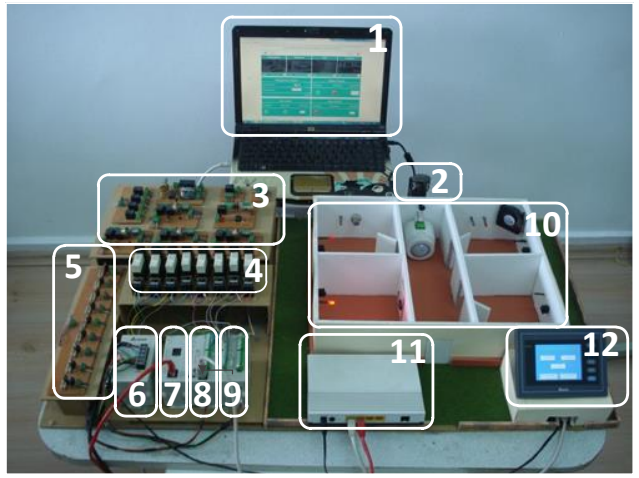

Figure 3

A general view of smart home system

2.2 Software Infrastructure

Hardware and software components of the realized smart home application are consisted of user, web, server, computer, PLC, operator panel and smart home components, and program and circuitry prepared for these components.

For the control of intelligent home via the internet in real-time, a simple and convenient infrastructure is constructed based on the client/server architecture. This infrastructure is made up of client software, server software and database section. The client software is the web interface by which users can control the smart home system through the internet. The main task of the client software running on the server is to manage lighting, ventilation and security units placed in the smart home system. The client software can perform the changes made on itself by DLL (Dynamic Link Library) is named DMT positioned essentially on Delta Modbus Library. It is possible to access inputs and outputs, registrars, auxiliary relays and memories of delta PLC through the methods reserved to user over DLL named DMT imported to client software. Users need a computer, tablet or mobile device with internet access in order to connect to the system. The control software is kept on the server by which all communications of the smart home system are provided. The server works in both directions. It records commands received from the smart home to the data base and sends recorded control commands from database to the smart home through PLC. The database comes into play in this part of the study. All adjustments and operations related to the smart home system are recorded in the database. Reports on the status of smart home are given depending on user request and the time. C# programming language has been used for the client and server software, while SQL server program has been used for the database. These three units interact constantly with each other although they are involved in different tasks and processes. The interaction between these units and the developed system architecture are shown in the block diagram in Figure 4.

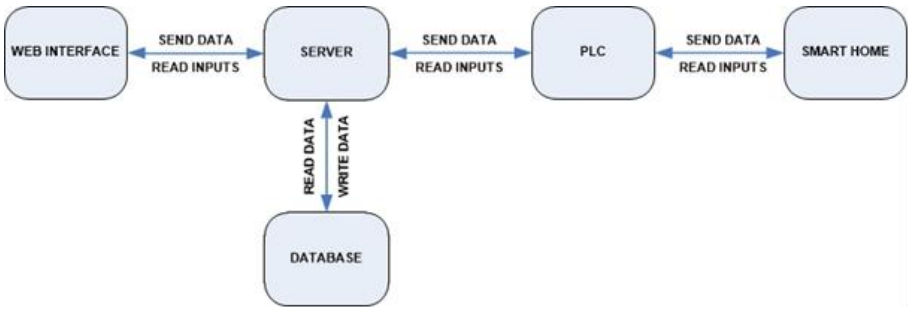

Figure 4
Software interaction

2.3 Web Interface

Part of smart home system that integrates with the user is the web interface. Here, the user can perform all the operations of a smart home system. The user gets the most up to date information about the smart home system in real-time using the web interface. Users can access all the rooms of the smart home system, the temperature value of the house, the motion control in the house (the thief), gas and smoke control and door control units through the web interface. In this way, they are able to manage smart home any way they want. The web interface is consisted of three parts as user home page, user control page and the reporting page. Login page is the part on which user logs in with the user name and password. In addition, pre-defined users on the database can log into the system. Figure 5 shows the home page.

Part of smart home system that integrates with the user is the control page. This page is working dynamically and any change that occurred in the smart home is reflected to control page. In the same way, a command given via the control page is submitted to the smart home. When the user looks at the control page he/she gets real-time information about status of the house. By using control page, the user can control lighting, security and air-conditioning units of the rooms. At the same time, adjustments related to these systems are able to make the system active/passive. The control page shown in Figure 6 faces to the user entering the user's name and password.

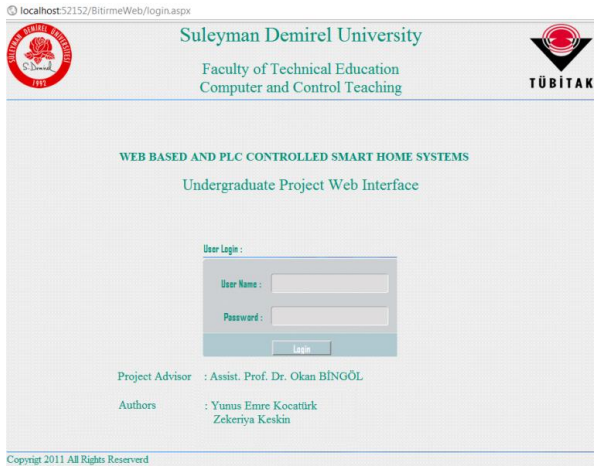

Figure 5
Home page

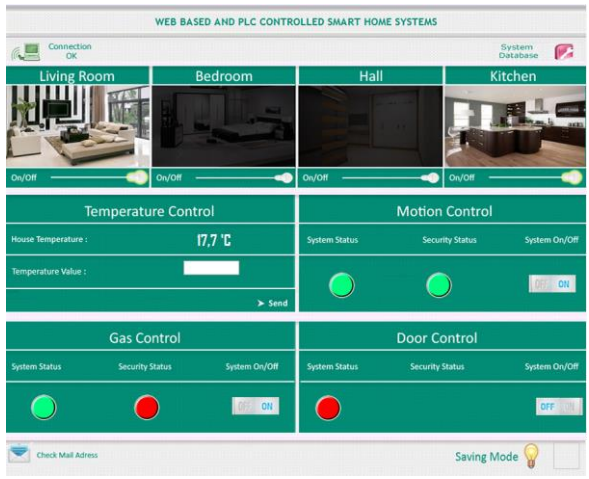

Figure 6
Control page

Reporting page brings the user all changes made by users on the internet or via the operator panel by taking from the system database. The user can see all changes about the home together with the date. Figure 7 shows the reporting page. The flow diagram describing the general operation of smart home system is shown in Figure 8.

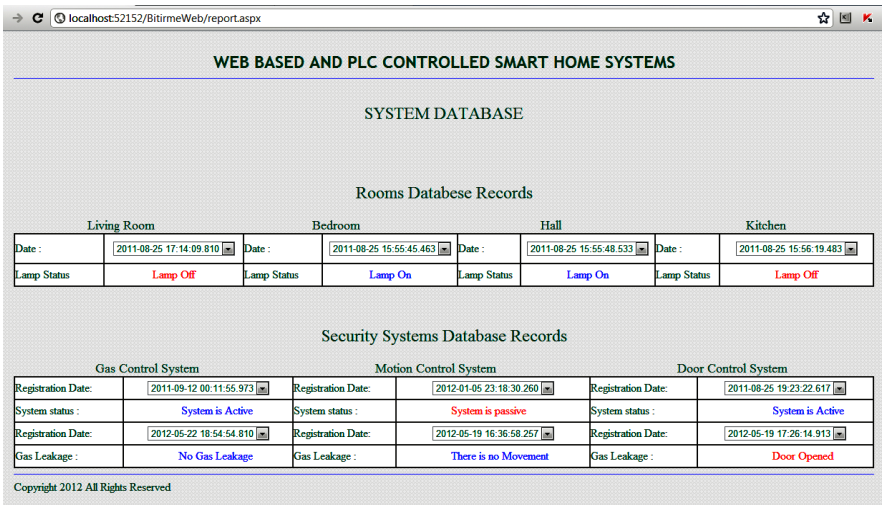

Figure 7
Reporting page

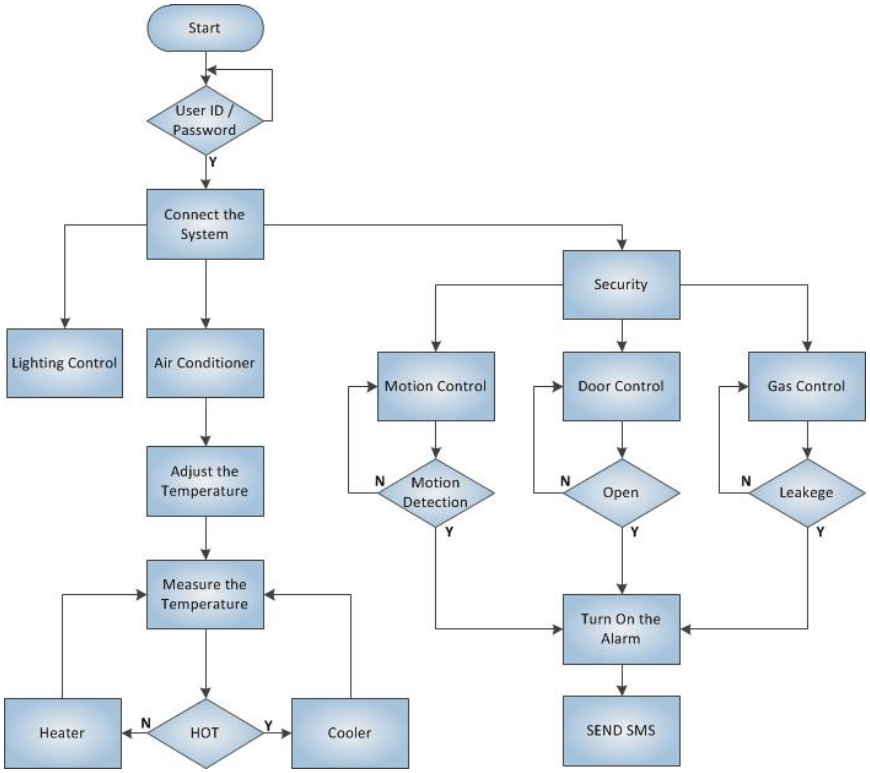

Figure 8
Flow diagram of smart home system

2.3 Operator Panel Interface

The control process of the smart home can also be carried out via the operator panel without the internet as mentioned above. Operator panel communicates directly with the PLC. All of the operations of the smart home system can be made via the operator panel. Lighting, security and air conditioning systems controlled and monitored via the internet in smart home system are also carried out via the operator panel. Four different interfaces were prepared on the operator panel for each operation process. The input interface is shown in Figure 9. The other three interfaces prepared for lighting, security, and air conditioning units can be accessed from input interface. Figures 10, 11 and 12 show lighting, security and temperature control panel interfaces respectively.

Figure 9
Operator panel home page

Figure 10
Lighting control panel

Figure 11
Security control panel

Figure 12
Temperature control panel

Conclusions

In this study, a web-based software and hardware for smart home automation system has been implemented. Smart home system was controlled by both PC and operator terminal called DOP-AS35THTD. The user interface is written using C # programming language. In the smart home system, controls of security (gas and smoke, motion, door control) and comfort (lighting and climate control) were carried out. In this study, PLC device of Delta Company having a sufficient number of digital and analog addresses was used for ease of information storage required for a smart home system and application on the operator panel. In addition, analog module with 4 analog input terminals and the Ethernet module are connected to the PLC.

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