ANDROID MOBILE DEVICES BASED AUTOMATION SYSTEM

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Abstract- In this study motor speed control implementation is presented establishing communication between android mobile device and PLC. As a first step for the implementation, firstly Bluetooth communication is established using an android based control software. Later PLC and Bluetooth communication is achieved by a developed mobile phone software. Finally compatibility among mobile phone, PLC and Bluetooth devices is achieved and inverter control is provided by commissioning an analog module for PLC device. Control of asynchronous motor is implemented by this controlled inverter. So that mobile phone is used instead of a controller device for applications requiring motor speed control using PLC. As a result, remote system control has been achieved for up to 10m distance.

Keywords- Automation, Remote Motor Control, Mobile System in Automation.

I. INTRODUCTION

In addition to the possibility to communicate with other devices by developing advanced applications, android mobile phones have the capability to communicate with TV, other mobile phones and computers using its internal equipments. Applications of mobile phone communication with PLC are established via wireless, SMS, serial port and Bluetooth communication methods.

Enabling PLC control via mobile communication lets us to control systems that require motor control remotely. The hardest way to establish a remote connection between Android mobile device and PLC is Bluetooth connection.

Because module designing is needed for system requirements since most PLC brands don't have Bluetooth module. Besides Bluetooth connection is a preferred method for both non-dense data transfer and short distance communication applications because of its slow communication and data losses during communication.

Android devices also have Bluetooth communication in addition to mediums establishing connection to outside world such as Wi-Fi, mobile internet, SMS and MMS. Short distance radio frequency (RF) is the technology that has ended Bluetooth (WPAN) cable connection. Silva et al succeeded to establish remote system control with mobile embedded systems using Bluetooth. There has to be Bluetooth feature in both the phone and the communicated device in order to establish data transfer between them. Both the usage of process or analysis of received/sent data or just data transfer can be aimed. Hanggoro et al studied control and observation of greenhouse using android mobile application. On the other hand Kok-Hua Teng et al remotely controlled Wi-Fi connected LED driver using android based controller. Jianping Cai et al successfully controlled bluetooth toy car using android equipments Zhang et al implemented android based multiple touch monitor system. Milton et al implemented web based remote observation and control application using android mobile phone.

Similarly various microprocessor and android based mobile phone applications became popular in recent years and applications and theoretical studies in very different areas can be found in literature.

In this study Siemens S7-200 PLC communication with android application has been established. Motor speed control has been achieved using PLC by establishing connection between PLC and smart phone via devised processor module. Control and observation of a short distance motor utilizing android based phones have been implemented by the developed application. Additionally not only asynchronous motor but also other types of motors that can be controlled by PLC's frequency converter, valves and switches can be controlled by mobile phone by following this study and setup.

II. SYSTEM HARDWARE AND DESIGN

System block diagram of the plant (system) is given in "Fig.1" In this system a mobile device having necessary control and communication program is connected to PLC by utilizing a module devised with Bluetooth. So that a communication medium is established between the mobile device and PLC. At this stage, as in the classical PLC control methods, asynchronous motor is controlled by frequency converter which in turn is controlled by PLC analog module. Data transferred over mobile phone with required hardware are sent to PLC using communication module. Here analog input module providing analog data input transfers data to frequency converter in consistent with PLC code and data flow to motor is established by frequency converter which is configured with motor parameters at the beginning.

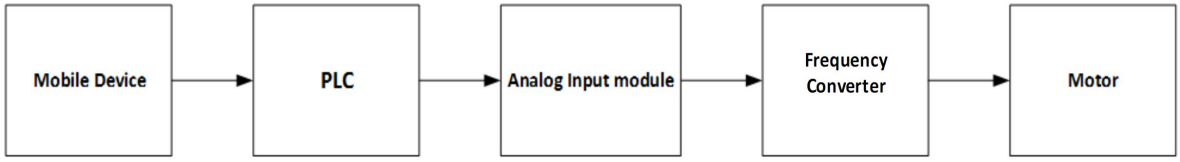
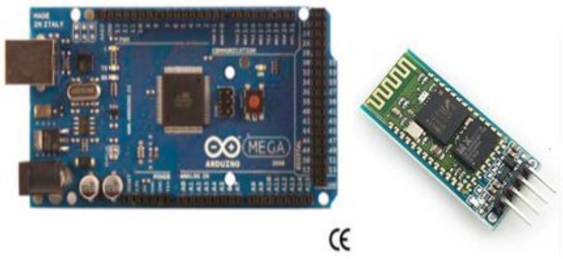


Figure 1. System Block Diagram

A. Communication Module

Even though Siemens company portfolio has devices to be used in the system such as GSM and Wireless, PLC external communication part doesn't include Bluetooth module.



(a) (b)

Picture 1. Arduino Mega(a) and HC-06(b)

As a result an internal circuit is needed to establish communication between phone and PLC. For that reason Arduino Mega 2560(Pic 1-a) and Bluetooth port HC-06(Pic 1-b) is used for this internal circuit

B. S7-200 PLC The programmable logic controller, or PLC, is a widely used control system for controlling industrial processes. The PLC systems were introduced in the 1970's with the purpose of replacing the existing relay logic systems. These PLC systems had no memory and only a few inputs and outputs. From the 1970's until today, the PLCs have been developed and have become the most common choice for industry control, mainly because of their simplicity and reliability. Advantages of PLC-systems are for example: a robust construction results in a reliable system; easy reprogramming; and cost effective for controlling of complex systems. These advantages result in PLCs beingsuitable for industrial environments. The PLCs hardware structure can be divided into five major parts, which are: CPU, memory, power supply, communication board, respectively input and output units, or I/O:s. A brief introduction about each part can be found in the corresponding subchapter.

CPU: The CPU is often referred to as a microprocessor that coordinates and handles the PLCs activities. The CPU contains a read-only memory, or ROM, where the basic instruction set and the boot loader are stored. Another part of the CPU is the electrically erasable permanent read-only memory, or EEPROM, which contains the programmed logics.

Memory: The memory consists of a flash memory which contains a copy of the user control program converted into binary numbers. This memory is often referred to as the user memory and is divided into blocks, which have separate functions. For example one part of the memory is used for storing I/O values and one part is used for data storage. Power supply: The power supply is used as an energy resource and can be an external or an internal module. Common supply voltage levels are 24 VDC or 220 VAC. The power supply is normally not used to power the external equipment, in order to ensure a separate voltage supply to the PLC. This will lower the risk of the industrial environment affecting the PLCs' power supply.

Communication board: Communication boards can be used to connect to networks, for example PROFIBUS and Ethernet, but also for programming. The type of communication board will vary depending on the task. Usually, the PLC is provided with a communication board, which allows connection to a personal computer with the correct software installed. This results in the possibility to load programs directly into the CPU.

Inputs and outputs: In order to monitor and control a process the PLC will need inputs and outputs. The inputs and outputs can, depending on the manufacturer, be mounted directly on the CPU-unit or added as external modules.

Inputs are categorized into two major types, digital or analog. A common analog input level is a current signal of 4-20 mA. Outputs are also categorized into either digital or analog. The International Electro-technical Commission publishes standards for electronic and electric products. The international standard IEC 61131 offers a collection of standards for PLCs. IEC 61131 consists of nine parts, which explain technical descriptions to be fulfilled by the PLC manufacturers. The standards were developed to make it easier for the end user by coordinating the many different PLCs manufactures. PLCs can be programmed using various programming languages. Four of them, which are standardized in IEC 61131-3, will be covered in this Subchapter. These languages are: Ladder diagram, structured text and Function block diagram. Ladder diagram: Ladder diagram, or LD, is probably the most common choice for PLC programming. It is a graphical programming language, which resembles electrical schematics. Inputs are drawn as switches, either in series or in parallel, and connected to one or several outputs. This graphical design makes the language simple and even

a non-programmer with electrical background can understand it. Ladder diagrams are the ideal choice for programming sequential event processes. However, more complex functions such as a PID controller are difficult to implement in this language. Structured text: Structured text programming, or ST, uses predefined statements and program subroutines to change variable values. An important difference from instruction list programming is that the program is run several times in a seconds and not only when an event occurs. Structured text programming is more similar to common high level languages than other PLC programming languages. Function block diagram: Function block diagram, or FBD, is a graphical programming language where logic gates are connected in a sequence. Function block diagrams are most suitable for small program, since the program is still really easy to follow. The logical gates will require some space on the screen and therefore large programs will not be appropriate for this language.

C. EM 235 Analog Input Module

One module is used in the system for speed control. EM 235 analog modules are 12 bits. A numerical value corresponding to an analog value is converted in 140 microseconds. It has 4 analog inputs and 1 analog output combination.



Picture 2: Siemens Micromaster 420/440 supply, command and motor connection

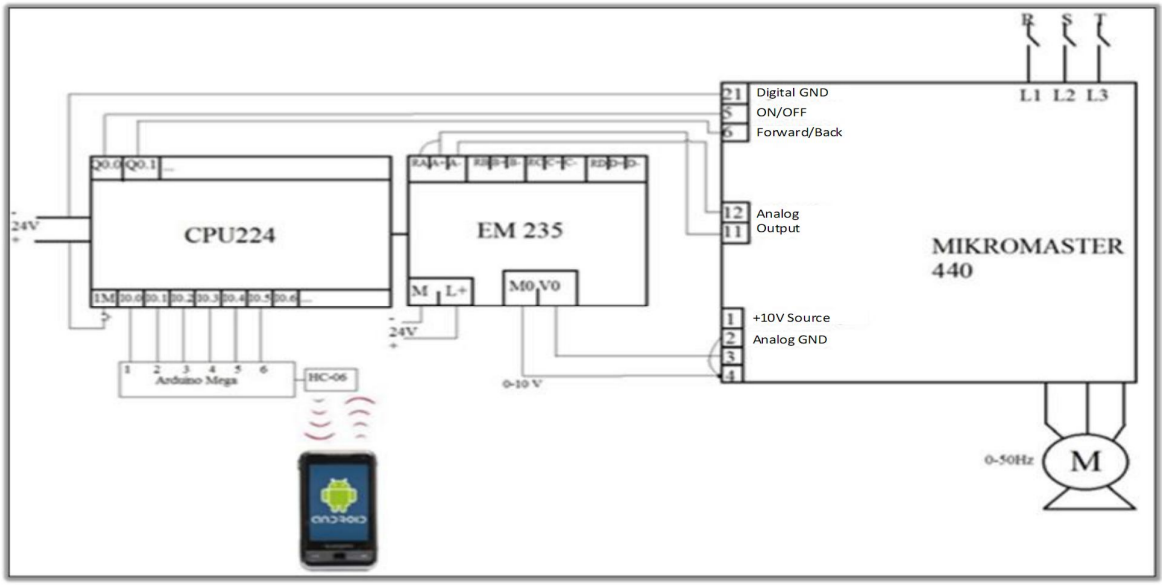


Figure 2: PLC-Motor Connection

D. Frequency Converter

In this study Siemens Micromaster 440 is used. MICROMASTER 440 devices are frequency converters to be used to control speed and moment of three phase AC motors.

Frequency controllers are devices to be controlled by microprocessors and also their current and voltage control are implemented by using isolated gate bipolar transistor circuit (IGBT) Motors can be run at desired speeds by utilizing a special puls width modulation method with variable frequency. Frequency converter and motor are protected from electrical noises by wide range protection functions. MICROMASTER 440 (Pic 2) can also be used for advanced motor control applications using extensive parameter list.

III. COMMUNICATION AND COORDINATION

In the coverage of this study, firstly motor connection of frequency converter that should have pre-entered parameters, secondly establishment of connection between frequency converter and analog input-output

unit (EM235) and lastly connection between prepared interval circuit and PLC need to be made.

A. Initial parameter adjustment of Frequency Converter Initial startup parameters are adjusted by P codes by pressing P button (Pic.3) located on the input panel of Micromaster 440. Here initial values (table 2) are given correspondingly to asynchronous motor parameters in "table 1" that were found in an experiment in Gazi university Technology Faculty Electrical–Electronics Engineering laboratory.

Technical modular connection between motor and PLC is given in "Fig.2". Parameters required for coding Micromaster 440 frequency converter are entered regarding its plate values and are indicated in "table 2".



Picture 3: Mikromaster440 Operator Panel

Table 1: AC Asynchronous and DC Motor Plate

Feature	Value
Volt Δ	220
Volt Y	380
Hz	50
Ampere Δ	3.6
Ampere Y	2.1
kW	0.75
cos Ψ	0.75
1/min	1370

Table 2: Micromaster Code Parameters

P Code	Value	Explanation
P0010	1	Fast commissioning
P0100	0	Which norm to work
P0304	380	Nominal motor voltage (Wye connection has been used)
P0305	2.1	Nominal motor current
P0307	0.75	Nominal motor power
P0310	50	Nominal motor frequency
P0311	*	Nominal motor speed
P0700	2	PZD command
P1000	2	Frequency adjustment point selection
P1080	0	Minimum frequency
P1080	50	Maximum frequency
P1120	1	Motor speed rise time
P1121	1	Motor speed fall time
P3900	1	Fast parameterizing

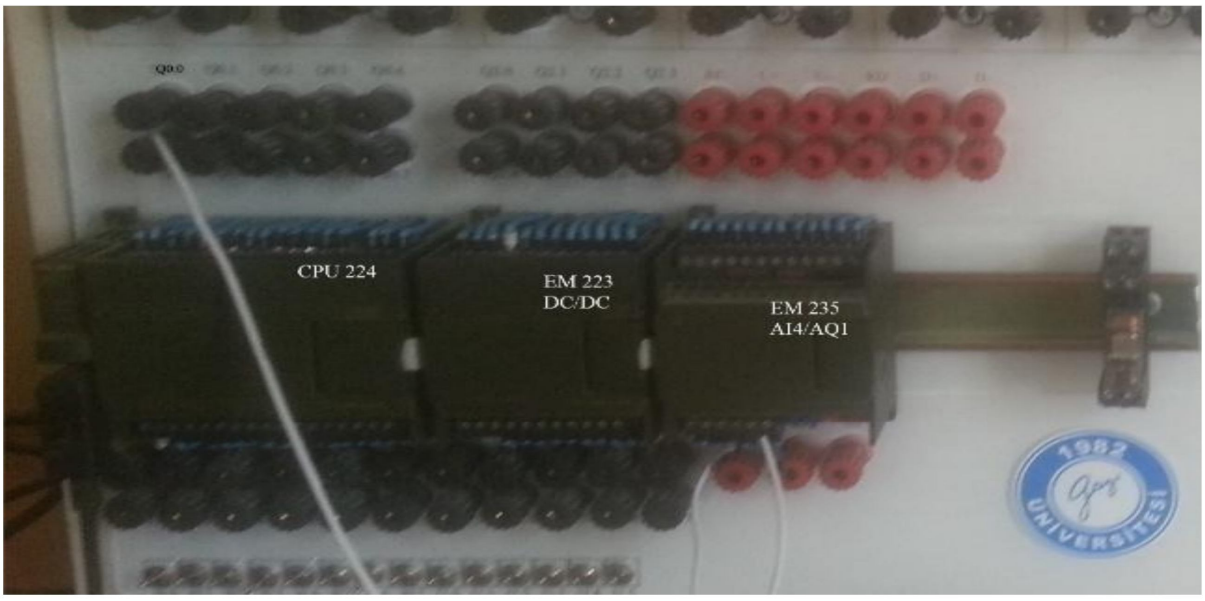


Figure 3: EM235 Connection

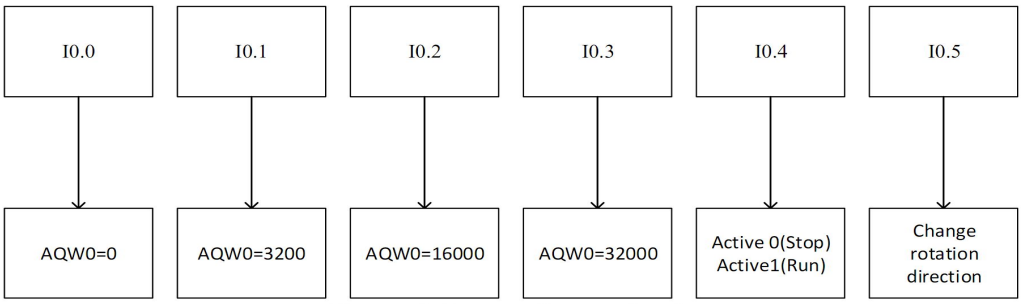


Figure 4: Button Categorization

After entering these parameters, required steps for frequency converter are completed. Maximum and minimum frequencies are given as 50 and 0 respectively. Fall and rise times are 1 second.

B. EM 235 and MIKROMASTER 440 Connection

Connection type and structure are given in "Fig 2" and "Fig 3". Cable connections are made regarding datasheets and necessary pin connections are also made respectively HC-06 module is connected to Arduino by making reverse connection of Rx and Tx excluding 5V and ground connections. In other words reverse connection is made by connecting Rx to pin 11 and Tx to pin 10 on Arduino PWM inputs while the code indicates Rx as pin 10 and Tx as pin11.

C. PLC Software

As in written PLC code in "Fig.4 and Pic 4" "move" commands have been used and values of AQW0 and 0-32000 interval were assigned to PLC inputs (table 3). Besides I0.4 and I0.5 inputs were used for initial startup of motor (to achieve active 0) and reverse direction run

```
PROGRAM COMMENTS
Network 1    Network Title
Network Comment
LD      I0.0
MOVW    0, AQW0
Network 2    Network Title
Network Comment
LD      I0.1
MOVW    3200, AQW0
Network 3    Network Title
Network Comment
LD      I0.2
MOVW    16000, AQW0
Network 4    Network Title
Network Comment
LD      I0.3
MOVW    32000, AQW0
Network 5
LD      I0.4
=       Q0.1
Network 6
LD      I0.5
=       Q0.2
```

Picture 4: PLC STL Code

Table 3: Inputs from PLC Code and Scaling

Digital Input	Analog QW	Analog value	Frequency value
I0.0	0	0V	0Hz
I0.1	3200	1V	5Hz
I0.2	16000	5V	25Hz
I0.3	32000	10V	50Hz

D. Communication unit between mobile phone and PLC

HC-06 module is connected to Arduino by making reverse connection of Rx and Tx excluding 5V and ground connections.

In other words reverse connection is made by connecting Rx to pin 11 and Tx to pin 10 on Arduino PWM inputs while the code indicates Rx as pin 10 and Tx as pin11 Besides relay is used in order to make the system compatible with the PLC that works with 24V and has 5V output sharing a combined ground with the circuit at the same time.

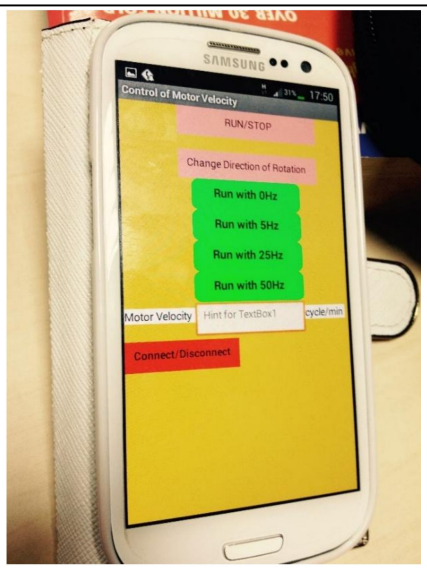
Connections are made as follows: Analog 1 output to I0.0 input, analog 2 output to I0.1 input, analog 3 output to I0.2 input, analog 4 output to I0.3 input, analog 5 output to I0.4 input and analog 6.output to I0.5 input. Each connection made is driven by a relay.

E. Android-Arduino Software and outputs

SET-RESET conditions are determined by sending HIGH or LOW data from 1,2,3,4,5 and 6 pins which are controlled by the Arduino code whose algorithm is depicted in "Fig 5" that sends information via Bluetooth.

Android code implements steps in software interface shown in "Pic 5" when synchronized with HC-06 mobile phone to send data.

Basically each button in the software determines set – reset data transfer between arduino mega output pins and their corresponding inputs on the PLC. M2invertor is used for this application "Pic 6".



Picture 5: Android Application

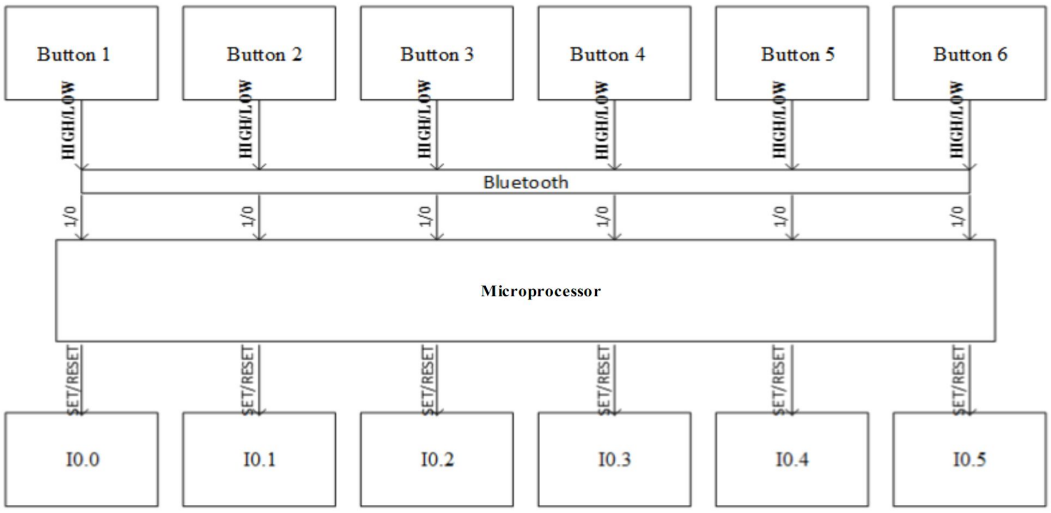
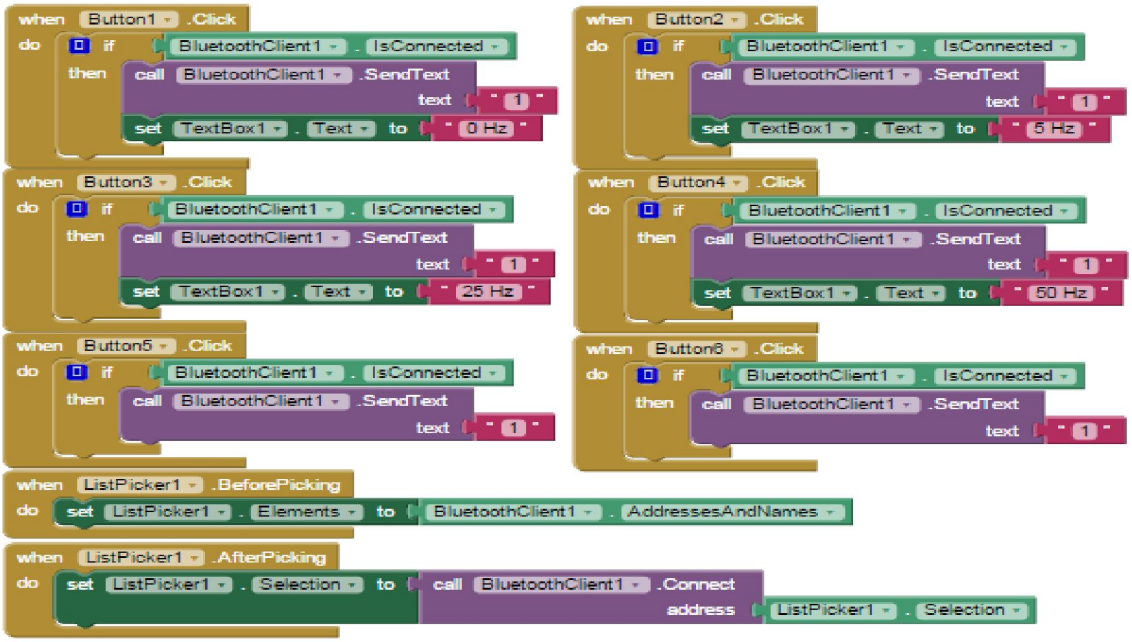


Figure 5: Android Code Algorithm and sample process



Picture 5: Some Part of Android Code and Program Algorithm

IV. RESULTS

Mobile phones, indispensable part of our everyday lives, also started to become popular in technological areas. Besides their common application areas such as smart houses, android applications, they are also used in remote applications by using their integrated hardwares such as Wi-Fi and Bluetooth. These features presented us more variety in terms of control applications. Multi task implementations and also system tracking and control are made possible by commonly used mobile phones.

In this study named “automatic motor control”, set-reset data have been sent to arduino pins by a software installed in Android and inputs that are connected to pins have implemented “move” or “output” processes that were previously coded in PLC. Motor speed has been controlled by these transferred data that were sent to frequency converter via analog input-output unit. So that command and control by using mobile phone can be achieved for any type of control or automation system that requires motor control.

Multi-motor speed control can be done by a single PLC and multi-PLC control can be achieved by a single mobile device. In this study result, many systems can be controlled with a mobile device on many PLCs. In examples, twenty systems, motors, valves and switches, was controlled with only a mobile phone on three PLCs. This makes it easy to follow and a new method of automation. Besides a solution that meets industrial expectations has been produced for PLC systems which lacks Bluetooth module. An interface has been created in order to developed software on Android operating system.

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