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Research Article

PLC-based Industrial Hardware Control with Mobile Application

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Abstract

Recently, mobile and its various applications have become widespread. Since these applications provide many advantages in industrial control systems, it is considered as a low cost and portable SCADA or HMI. The designed mobile application can replace the control panels used in the field of industrial automation. In this study, as hardware control with mobile application, conveyor system control with mobile application was made. The connection between the mobile and the PLC is established using the TCP/IP communication protocol. S7-1200 PLC and S7-1500 PLC developed by Siemens were used in this system. In addition, a Switch is used to create the network environment of the PLCs and mobile device. In this conveyor system, the iron and plastic objects entering the system are separated from each other, and at the end of the process, the plastic objects are placed on the iron objects and removed from the conveyor. During this process, the values and transactions that occur in the system are monitored and controlled in Real Time via mobile. This study provides ease of development of mobile applications for any Industrial system that may include any SCADA or HMI. The development method of the mobile application and the communication of the established system will add new developments to industrial systems in many areas.

Keywords: Mobile application, Industrial hardware, PLC, TCP/IP, Conveyor system, Control.

Mobil Uygulama ile PLC Tabanlı Endüstriyel Donanım Kontrolü

Öz

Günümüzde mobil ve çeşitli uygulamaları yaygınlaşmıştır. Bu uygulamalar endüstriyel kontrol sistemlerinde bir çok avantaj sağladığından dolayı, düşük maliyetli ve taşınabilir bir SCADA yada HMI olarak düşünülmektedir. Tasarlanan mobil uygulaması endüstriyel otomasyon alanında kullanılan kontrol panolarının yerine geçebilmektedir. Bu çalışmada, Mobil uygulaması ile donanım kontrolü olarak, mobil uygulaması ile Konveyör sistemi kontrolü yapılmıştır. Mobil ve PLC arasındaki TCP/IP haberleşme protokolü kullanarak bağlantı kurulmuştur. Bu sistemin içinde Siemens tarafından geliştirilen 2 adet S7 PLC kullanılmıştır. S7-1200 PLC ve S7-1500 PLC kullanılmıştır. Ayrıca, PLC'leri ve mobil cihazının ağ ortamı oluşturmak için bir adet Switch de kullanılmıştır. Bu konveyör sisteminde, sisteme giren demir ve plastik nesneleri birbirinden ayırıp, işlemin sonunda plastik nesnelerin demir nesnelerin üzerine oturtması ve konveyörden çıkartmaktadır. Bu işlem sırasında, sistemde oluşan değerler ve gerçekleşen işlemler mobil üzerinden Real Time olarak takip ve kontrol edilmektedir. Bu çalışma, her türlü SCADA ya da HMI içerebilecek herhangi bir Endüstriyel sistem için mobil uygulamaların geliştirme kolaylığı sağlamaktadır. Mobilin uygulamasının geliştirme yöntemi ve kurulan sistemin haberleşmesi, Endüstriyel sistemlere birçok alanda yeni gelişmeler katacaktır.

Anahtar Kelimeler: Mobil uygulama, Endüstriyel donanım, PLC, TCP/IP, Konveyör sistemi, Kontrol.

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1. Introduction

Today, much attention is paid to the field of industry. Due to the studies on the industry that started in the last Industrial Revolution, there have been great developments in production. The use of machines and computers in factories and production lines for faster and safer production has had a great impact on the industry. In the last years, many researchers have widely preferred conveyor belt studies for both industrial and academic studies. These studies are carried out successfully in different applications (IoT, Mobile application, PID, Fuzzy Logic etc.) by using certain hardware (PLC, Control cards, FPGA etc. cards) for conveyor belt studies [1-4].

In literature studies, PLC control with mobile application, TCP/IP communication protocol, remote PLC control, object sorting conveyor system etc. [5-9]. In the thesis prepared by Fan Chen, Zhizheng Wu, Pan Luo and Zhuoer Shen In 2020, Design of SCADA System for Stainless Steel Pipe Production Line. Scada is designed for PLC in Visual Studio using S7.NetPlus C# driver [10]. In the article published by Öznur Şengül in 2020, color-based object separation was performed on the conveyor belt using PLC and Operator panel. Object recognition and parsing process has been processed in real time [11]. In the thesis prepared by Arif Tunuz in 2019, problems, solutions and gains in IoT application in iron and steel industry. Distance, cyber security and magnetic field problems encountered in the implementation of IoT in iron and steel industry were investigated and the corresponding solution suggestions were presented [12].

In this study, Industrial Automation system was controlled by using Internet of Things technology. As shown in Figure 1.1, the modules to be used in the system to be created in this study are; PLC S7-1200 and S7-1500 will be used as industrial controllers. The mobile application, which is also designed, will be installed on the phone device and the system will be audited via mobile. The communication between the telephone device and the PLC connected in the same local network with the switch is ensured. With the mobile application, the process of getting the result from the PLC, giving the command to the PLC, in short, controlling and monitoring the PLC is done with the phone connected to the same local network. The reason for using the local network is because it is very common to communicate over PLC TCP. It contains function blocks that enable communication over TCP in PLC. Also, since the control takes place over the local network, it prevents dangers such as any hacker attack that will occur over the Internet Servers. In this study, communication of more than two different devices in the same local network over TCP data transmission protocol is carried out. It provides communication between PLC and Mobile device using TCP protocol.

Figure 1.1: Topology of the system

Easy design and programming of mobile applications provides convenience in automation control. System control is performed over the IP address determined in the Switch with PLC. In the local network, the Master (Mobile) is the Slave (PLC) and is responsible for routing in the Mobile data exchange process.

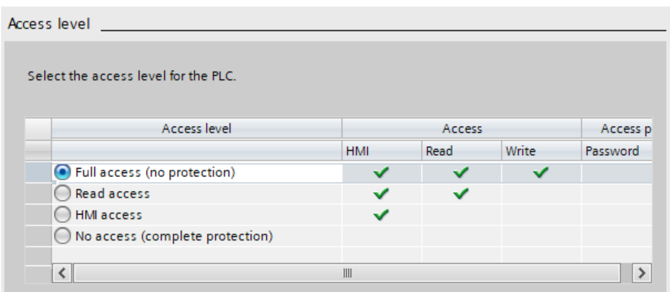
2. Communication of the System

S7netPlus is a PLC driver that works with Siemens PLCs and only with Ethernet connection. This means that PLCs must have a Profinet CPU or a profinet external card (CPxxx card). S7.NetPlus is written entirely in C#. Compatible with S7.NetPlus, S7-200, S7-300, S7-400, S7-1200, S7-1500 [13]. Thanks to this driver, since PLC can be accessed directly from the phone, it does not require any extra software such as TCP function blocks in the PLC software. The S7.NetPlus driver has codes to be used in the Master device connected to the PLC, certain commands and sequences to establish a communication bridge. As mentioned, Visual Studio was used to develop the Mobile application. After adding the S7.Net driver to the program, a certain code sequence must be used to connect the Master device to the Slave device (PLC). As shown in Figure 2.1, this sequence starts from the process of determining the target PLC type, IP address, Racks and Slots. Then, by sending a TCP connection request to the PLC with the plc.open() command, as seen in Figure 2.3, the Master (computer or mobile) device will be connected to the S7 PLC when it receives a positive response. The default port for TCP/IP connections in S7 PLCs is 102 port. In most cases the PLC will only accept on port 102. As shown in Figure 2.2, in order for the PLC to respond positively to the TCP connection request and to establish the connection with the master device, full access feature (no protection) must be selected from the access degree option in the Protection and Security section of the PLC's settings via TIA Portal.

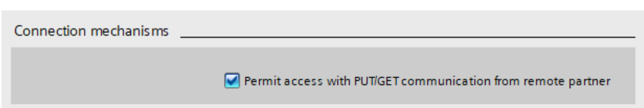
```
using (var plc = new Plc(CpuType.S71200, "192.168.2.15", 0, 1))
{

    plc.Open();


    byte[] db1Bytes = new byte[18];

    plc.Write("DB1.DBX0.0", true);


    plc.Write("DB1.DBX0.1", false);
    plc.Close();

}
```

Figure 2.1: C# code example that connects with S7 PLC on the master device and writes Boolean values to Data Blocks

In addition, PUT/GET communication with another partner must be allowed from the connection mechanisms option. By making these settings, the target PLC will respond positively to any TCP connection request and the master device will be able to establish a connection with the PLC.



(a) Full access (no protection)



(b) Permit access with PUT/GET communication in Connection mechanisms

Figure 2.2: Settings required to establish TCP connection in S7 PLC

After establishing a connection between the Master and Slave, it is the turn of the operation intended to be performed in this communication. The data exchange to be made with the PLC, by accessing the data blocks inside the PLC, the Master device performs value reading or writing at the addresses previously determined by the user. When the master device establishes the connection with the PLC, it cannot find the data block to be processed. Data blocks allow only optimized block access by default. As shown in Figure 2.3, when the Optimized block access requirement is removed from the Attributes section of the data block settings, the master will be able to read or write the data in the specified block according to their addresses.

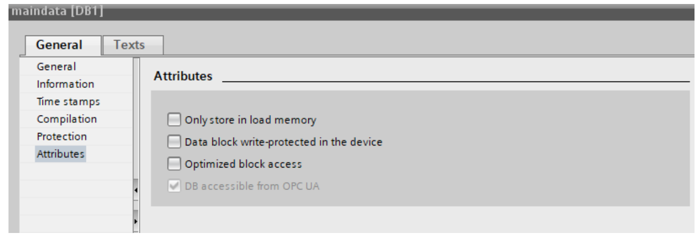


Figure 2.3: Removal of optimized block access requirement

After the optimized block access requirement is removed, the offset value for each variable will be seen inside the data block. These offsets show the location of each variable in memory. As seen in Figure 2.4, the memory space of each variable varies according to its type. Boolean type variables occupy 1 bit of memory. Integer values take up 2 bytes (16 bits), Real values take up 4 bytes and String values take up 256 bytes.

Data_block_1

	Name	Data type	Offset	Start value
1	Static			
2	testbool	Bool	0.0	false
3	testbool1	Bool	0.1	false
4	testint	Int	2.0	0
5	testword	Word	4.0	16#0
6	testbool2	Bool	6.0	false
7	testbool3	Bool	6.1	false
8	testreal	Real	8.0	0.0
9	teststring	String	12.0	''
10	testbool4	Bool	268.0	false

Figure 2.4: Variable offsets in the data block and space coverage by type

As shown in Figure 2.1, True value will be written to DB1.DBX0.0 address in ‘plc.write’ command. DB1; It stands for data_block_1. In DBX, the type of the variable is set to Boolean in the data block. 0.0 is the previously mentioned offset; is the address of the space it occupies in memory. Likewise, False will be written to the address DB1DBX0.1. The address DB1.DBX0.0 matches the address of the ‘testbool’ variable seen in Figure 2.4. The address DB1.DBX0.1 matches the address of the testbool1 variable seen in figure 2.4. When the code shown in Figure 2.1 is run, the value of the ‘testbool’ variable will be ‘True’, and the value of the ‘testbool1’ variable will be False.

3. Operating Object Separating Conveyor System as Hardware Control with Mobile Application Implementation

Conveyor application was carried out as an example of PLC control with mobile. The main job of this conveyor is to separate plastic and iron. After separating the iron and plastic, he removes the piece of plastic so that it sits on top of the piece of iron. In this process, it turns the system on and off, counts the number of iron and plastic parts, gives separation information and transfers the belt speed to the mobile application in real-time. In addition, the equipment on the conveyor is manually controlled by the mobile application. Figure 3.1 shows the implemented conveyor system.

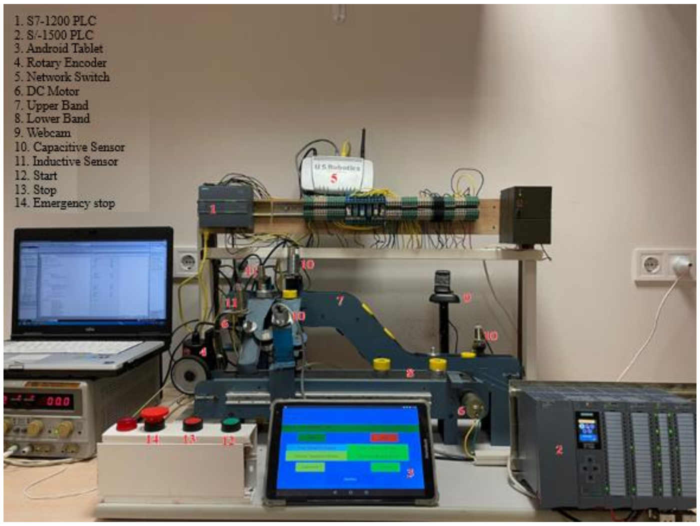


Figure 3.1: Conveyor system

Two PLCs are used in this sample application. Encoder application was made with S7-1500 PLC. This Encoder calculates the revolutions per minute of the normal belt of the conveyor and transfers this value to the mobile application in real-time. S7-1200 PLC is connected to the Conveyor. S7-1200 PLC is responsible for directing the plastic and iron objects brought by the toothed conveyor to separate belts and placing the plastic objects on the iron objects. It also transfers the steps and results of this process to the mobile application in real-time. The topology shown in Figure 3.2, the mobile application and the object sorting conveyor system as a hardware control application, the network map established between the PLCs and the phone, and the material used in the system are shown.

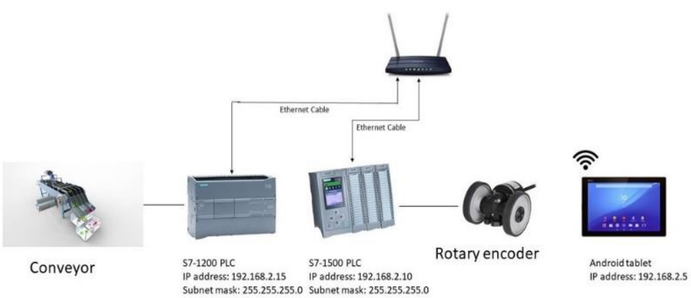


Figure 3.2: Object separating conveyor system as an implementation of hardware control with mobile application

As shown in Figure 3.3, the algorithm shows input, output and process flow of the system. Also the mobile app monitoring of the system is shown in the algorithm. Basically, the system works in full automatic after run button is pressed. But the same time, object separation can be controlled manually from the mobile app, just emergency situations where it is required to intervene the process of the system.

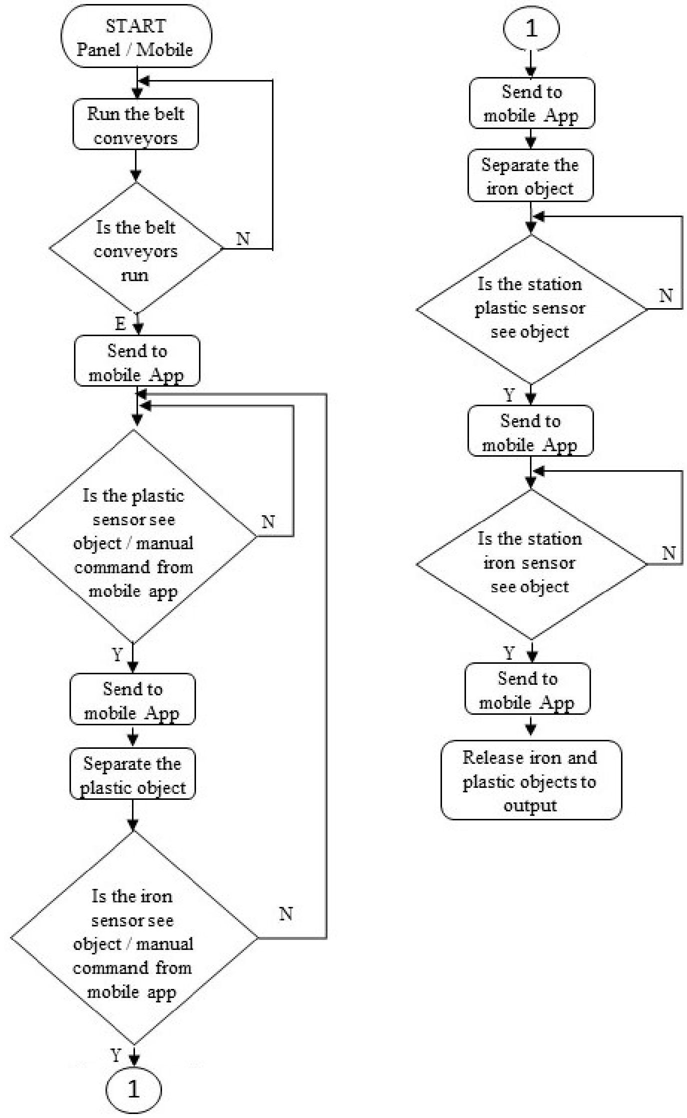
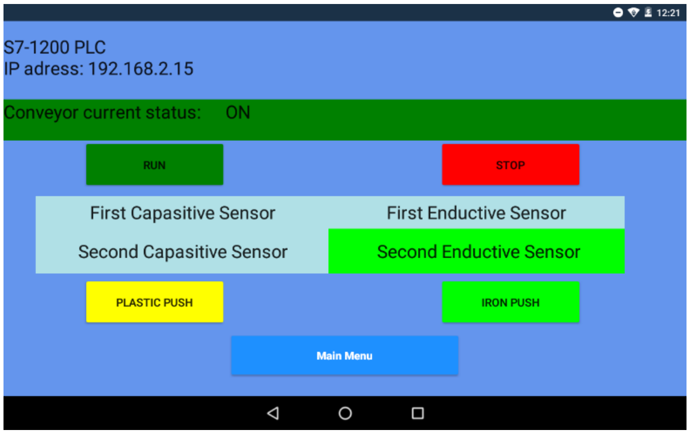


Figure 3.3: System Algorithm

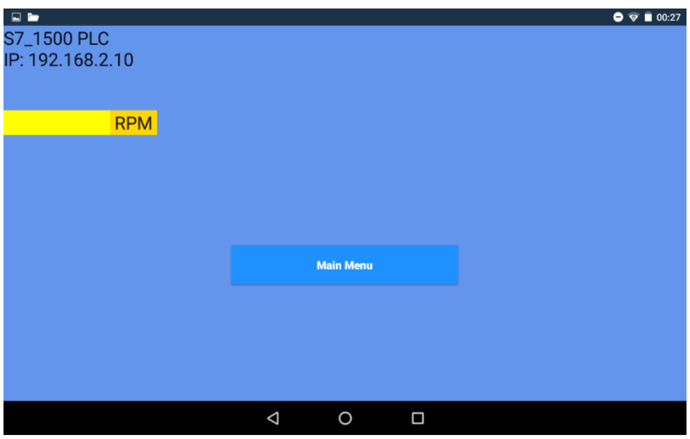
3.1 Development of Mobile Application

In this study, the developed application is designed to provide the best interaction with the user according to the hardware. The designed application has been developed for mobile device using the Android operating system.

The developed application consists of three interfaces: the interface, the interface that displays the speed of the normal belt of the conveyor in real time, and finally the interface that provides control of the conveyor and monitors the separation process. In the interface shown in Figure 3.4(a), the speed information of the normal belt is displayed in real time. This displayed information is calculated by the S7-1500 PLC. Each interface has different C# code according to the operation it will perform in the application. The result of the operation performed in the code part or the command entered from the interface is transferred to the main code. In the interface shown in Figure 3.4(b), the process of controlling the conveyor and following the object separation process is performed. In this interface, the working status and whether the sensors see the objects are reflected on the screen in real time. The color change of the box in which these data will be displayed, as seen in Figure 3.4(b), turns ON when the system is in operation, and where it is written turns green. If the system is not active, OFF is written and the place where it is written turns into red. The outputs of the sensors change color to show whether they see an object or not.



a) Interface that performs the control of the conveyor and monitors the separation process of the objects



b) Screenshot of the interface of the developed application, which includes the speed of the normal belt

Figure 3.4: Application of Interfaces

Mobile Application Pseude Code for S7-1200 PLC

```
Target plc info (type: 1200,
IP: 192.168.2.15, rack 0,slot 1)
Connect
Run button clicked
(
Write True to DB1.DBX0.0
Set DB1.DBX0.0 to False
)
Target plc info (type: 1200,
IP: 192.168.2.15, rack 0,slot 1)
Connect
Stop button clicked
(
Write True to DB1.DBX0.2
Set DB1.DBX0.2 to False
)
Target plc info (type: 1200,
IP: 192.168.2.15, rack 0,slot 1)
Connect
Iron push button clicked
(
Write True to DB1.DBX0.3
Set DB1.DBX0.3 to False
)
Target plc info (type: 1200,
IP: 192.168.2.15, rack 0,slot 1)
Connect
Plastic push button clicked
(
Write True to DB1.DBX0.4
Set DB1.DBX0.4 to False
)
Execution timer every 250 ms
(
Target plc info (type: 1200,
IP: 192.168.2.15, rack 0,slot 1)
Connect
(
Read DB1.DBX0.5
=> Status control
Read DB1.DBX0.6
=> Cap sensor 1
Read DB1.DBX0.7
=> Cap sensor 2
Read DB1.DBX1.0
=> End sensor 1
Read DB1.DBX1.1
=> End sensor 2
If status control = true
Text = on and label is green
Else If status control =false
Text = off and label is red
If cap sensor 1 = true
Label is yellow
If cap sensor 2 = true
Label is green
If end sensor 1 = true
Label is yellow

If end sensor 2 = true
Label is green
)
)
```

Mobile Application Pseudo Code for S7-1500 PLC

```
Execution timer every 1000 ms
(
Target plc info (type: 1500,
IP: 192.168.2.12, rack 0,slot 1)
Connect
(
Read DB2.DBX6.0
Print value on screen
)
```

Figure 3.5: Pseudocode for mobile application

In Figure 3.5, a Pseudocode for mobile application shown. This code show the programming algorithm of establishing connection with PLC, read and write data to PLC.

3.2 Real Time Operation of the System

In this part of the study, the phases of monitoring, examining and testing the system in real time were carried out.

3.2.1 Calculating Belt Speed with S7-1500 PLC

By placing the encoder on the normal belt, it calculates how many revolutions per minute that belt makes. Encoder S7-1500 is connected to Time counter module on PLC. As shown in Figure 3.6, the High Speed Counter block is used in Tia Portal. Measured Value represents how many revolutions per minute the belt rotates. This measured value is displayed in Data Block 2 and transferred to the mobile application from there.

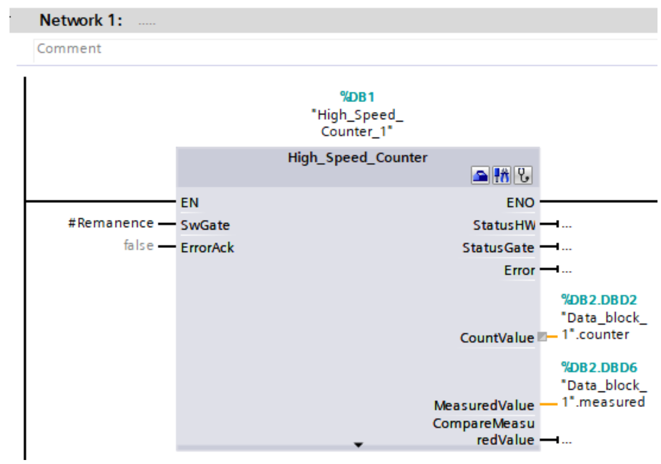


Figure 3.6: High Speed Counter

Equation (1) shows the speed counts/millisecond, where C_0 is the initial value of counts at time T_0, and C_1 is the value of counts at T_1. While T_0 and T_1 are the count time [14]. In this study, $(T_1 - T_0)$ is considered as 250 milliseconds, which is set from PLC. As so, the speed is determined every 250 milliseconds. As for counts value, C_0 is always set to zero, C_1 is set to zero and the count starts again every time after speed is determined, which is in this case is 250 milliseconds.

$$Speed = \frac{(C_1 - C_0)}{(T_1 - T_0)} \quad (1)$$

$$M_{RPM} = Speed \times \frac{60\ Seconds}{1\ minute} \times \frac{1\ revolution}{E_C} \quad (2)$$

In equation (2) shown above, after Speed is calculated, the M_{RPM} is determined by this equation. E_C stands for encoder's count, which is the value encoder counts every revolution, the encoder used in this study holds 400 counts every single revolution, so E_C value equals 400.

3.2.2 Operating the Conveyor System with the S7-1200

S7-1200 PLC is connected to the equipment of the conveyor. This PLC will perform parsing and other operations as mentioned before. In addition, it will be controlled via the Mobile application, as well as via the dashboard. In other words, conveyor control will be on both the Mobile application and the panel. In Figure 3.7, the Data block that the mobile application will access as the object sorting conveyor system S7-1200 PLC and the variables in it.

maindata					
	Name	Data type	Offset	Start value	Retain
1	▼ Static				
2	run	Bool	0.0	false	
3	buffer	Bool	0.1	false	
4	stop	Bool	0.2	false	
5	demir itme	Bool	0.3	false	
6	plastik itme	Bool	0.4	false	
7	status control	Bool	0.5	false	
8	cap sensor 1	Bool	0.6	false	
9	cap sensor 2	Bool	0.7	false	
10	end sensor 1	Bool	1.0	false	
11	end sensor 2	Bool	1.1	false	

Figure 3.7: S7-1200 PLC Data Block.

4. Conclusion and Suggestions

In this study, the aim sought from the hardware control with the mobile application has been successfully achieved. The mobile application developed in C# programming language, connecting with S7 PLCs and data exchange resulted in success. In any system installed with S7 PLCs, its mobile control has become usable according to the purpose of establishing that system and the operations performed. In this study, it is thought that the conveyor system, which separates objects as a hardware control application with its mobile application, provides a greater effect than any control panel or HMI, remote control and tracking.

In the conveyor system, real-time control and monitoring of the real-time processes resulted in maximum efficiency and success. This study can be taken as an example of hardware control with its mobile application for many systems in the industry. To make this work more advanced and useful, there are a number of operations. One of them; during the connection with the mobile device and PLC, in case the connection cannot be established, it is trying to provide the opportunity to transfer the reason for not connecting to the user. In addition, since this work takes place over the local server, it will be more effective and beneficial if it is done over the Internet server.

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