

Web-Based HMI for PLC Systems

Nikola Kukrić, Zorana Mandić, Tijana Begović, Slobodan Lubura

Abstract— Programmable Logic Controllers (PLCs) are widely used in industrial automation to control various processes and machines. Human Machine Interfaces (HMIs) are often used to provide a graphical interface for monitoring and controlling an industrial system. With the advent of web technologies, it has become possible to develop web-based HMIs that can be accessed remotely from any device with a web browser and internet connection. These web-based HMIs offer several advantages over traditional HMIs, including greater flexibility, scalability, and remote access capabilities. This paper provides an overview of the technology behind web-based HMIs for PLC systems. It explores the key components of a typical web-based PLC HMI system, including hardware, software, and networking protocols. The paper also discusses the advantages and disadvantages of using web-based HMIs for monitoring and control of PLCs and compares them to traditional HMI systems. The paper presents some practical examples of web-based HMIs for PLC systems, including the use of open-source software and the integration of cloud-based services.

Index Terms— Programmable Logic Controllers (PLCs), Human Machine Interfaces (HMIs), Web-based HMIs, traditional HMIs, plc remote access, industrial automation.

I. INTRODUCTION

PLCs are electronic devices that are programmed to perform logic, sequencing, timing, counting and arithmetic functions. PLCs are widely used to control various industrial processes and machines [1]. It is common to use them with HMIs, that enables a graphical interface for monitoring and controlling not only the PLC, but the whole industrial systems.

HMIs are used for communication between operator and industrial system, so it is necessary to provide simple interaction and use. As web technologies have become an indispensable part in many technology fields, it has become usual to create web-based HMIs. This enables remote access and control of a system from devices with internet connection.

Nikola Kukrić is with the Faculty of Electrical Engineering, University of East Sarajevo, Vuka Karadzica 30, 71123 Bosnia and Hercegovina (e-mail: nikola.kukric@etf.ues.rs.ba), ORCID ID (<https://orcid.org/0000-0001-7623-1305>).

Zorana Mandić is with the Faculty of Electrical Engineering, University of East Sarajevo, Vuka Karadzica 30, 71123 Bosnia and Hercegovina (e-mail: zorana.mandic@etf.ues.rs.ba), ORCID ID (<https://orcid.org/0000-0003-4993-9396>).

Tijana Begović is with the Faculty of Electrical Engineering, University of East Sarajevo, Vuka Karadzica 30, 71123 Bosnia and Hercegovina (e-mail: tijana.begovic@etf.ues.rs.ba), ORCID ID (<https://orcid.org/0009-0007-3413-3169>).

Slobodan Lubura is with the Faculty of Electrical Engineering, University of East Sarajevo, Vuka Karadzica 30, 71123 Bosnia and Hercegovina (e-mail: slobodan.lubura@etf.ues.rs.ba), ORCID ID (<https://orcid.org/0009-0006-1657-7607>).

Web-based HMIs can offer many advantages over ordinary HMIs, such as flexibility, adaptability, remote access capabilities and opportunity for improvements [2].

Web2PLC are developed by Siemens is one of options and most common options for implementing Web-based HMIs for PLC systems, and this principle has become popular due to the integration of internet technologies in industrial automation. Systems with these functionalities offer a lot of benefits and features. Some of them are remote access and monitoring, real-time control, and data logging and analysis [3].

An overview of the technology behind web-based HMIs for monitoring and control of PLC systems will be given in this paper. It describes the main components and working principle of a web-based PLC monitoring and control system. Advantages of this approach for monitoring and control of PLCs systems will be discussed. A comparison between classic and web – based HMIs is also given.

In addition, a solution for remote programming of the PLC station is briefly described. It is done via public IP address assigned to the station.

Overall, this paper is intended to serve as a useful resource for anyone who is interested in this field, by providing a comprehensive review of the technology behind web-based monitoring and control of PLC systems.

II. CLASSICAL VS WEB-BASED HMI

Classical HMIs are usually based on screens stored in the control panel. The first control panel was connected physically with PLC by point-to-point connection, as shown in Fig. 1. On displays in control panel only raw data is visualized. Later, other communication protocols were used so it was possible to control more than one PLC from a single panel. But, even with this approach, the number of connected devices is limited [4].

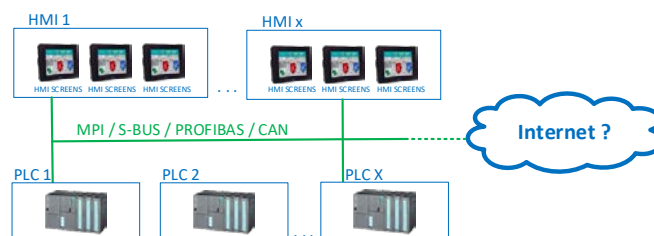


Fig. 1. Classical HMI with screens saved in the control panel and point-to-point connections between PLC and control panel.

The use of web technologies in HMI design enables the introduction of flexible client/server structure. PLCs act like web servers that contain web pages for displaying data. Clients are any devices with web browsers (PCs, control

panels etc.). A network of PLCs, that act as servers, and HMIs is shown in Fig. 2. This means that the visualization project is now stored on the controller and no longer on panels. As web panels only load web pages, data exchange and maintenance are simpler. Also, in this case the number of PLCs or HMIs connected mutually is unlimited because of client/server topology. If there is need, modifications are made only on the PLC, and they are available everywhere.

Web-based HMIs can be created using different web technologies (HTML, JavaScript) or platforms (Java, .NET). The easiest way to implement web-based HMI is to store a variety of HTML pages in PLC. These pages are usually static, so their content is not changeable. But there are ways of including dynamic data from controller in these pages through user programmable websites. In this case, HTML code contains predefined tags which are dynamically replaced with specific data when server receives a request. Dynamics of HTML pages can be achieved by using JavaScript [5].

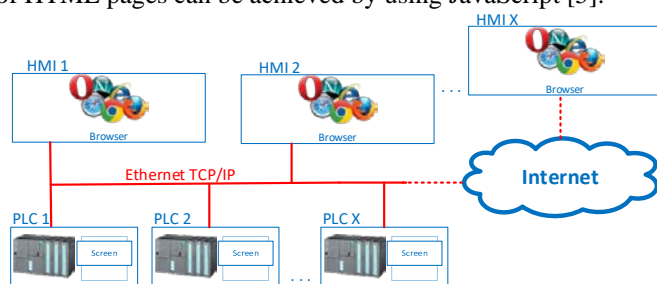


Fig. 2. Web-based HMI with screens saved in PLC with web server and display in web browser.

Comparison:

- Web-based HMIs are accessible from any device with internet connection while classical PLC HMIs are locally installed special purpose panels or PCs.
- Connectivity is also a difference; web-based HMIs are remotely accessible and classical HMIs are limited to one access point. Also, web-based HMIs are very customizable.
- Web-based HMIs are usually easy to implement as they are totally based on web technologies. While classical HMIs require special purpose complex software.
- Web-based HMIs are much more scalable than classical PLC HMIs as they are scaled for the needs of both small and large industrial applications.

To conclude this comparison, it is obvious that both classical and web-based PLC HMIs have advantages and disadvantages. Which one will be used mainly depends on the system's purpose and size. However, web-based HMIs are increasingly used as they are more scalable, flexible, and capable of remote access.

III. IMPLEMENTING WEB SERVER ON SIMATIC S7-300

SIMATIC S7-300 is the PLC, which was introduced by Siemens in 1996, inheriting SIMATIC S5 series. The S7-300 simple modular design offers flexible use, user – friendly

handling, and simple extension. It is suitable for low and medium performance ranges.

The SIMATIC S7-300 PLC system consists of several modules that can be used individually. These modules are central processing unit (CPU), a power supply unit (PS), signal modules (input/output modules), communications processor (CP), etc. The CPU executes the user's program and controls other modules. Different I/O modules (both digital and analog) are used to connect PLC with sensors and actuators, while PS unit provides required power to the system. CPs enable connection establishing by many interfaces [6].

For S7-300 system programming, the Simatic STEP 7 manager and TIA portal are used. It is a top-level software tool that enables hardware configuration, developing and testing user's program, interfaces configuration, and diagnostic and monitoring of the PLC system. STEP 7 is a user-friendly programming tool that allows users to write structured programs using different types of languages [7].

Scalability stands out as one of the main advantages of the SIMATIC S7-300 system. The system can be easily expanded if it is necessary. Adding additional I/O modules or upgrading the CPU enables the system to meet the requirements of different applications. Using different communication interfaces, it is possible to integrate S7-300 system with devices in the system [6].

The SIMATIC S7-300 system also offers many features and functions due to its modular design and scalability. Some of these functions are faster processing and higher productivity, extended diagnostic function, real-time monitoring, web server integration etc. Previously mentioned features improved the performance of the system, so it is proper for use in any kind of industrial applications [8].

Overall, the SIMATIC S7-300 represents a flexible and proven device which is widely used in industrial automation and control systems. It is a great solution for a wide range of applications in addition to its modular design, extensibility, and scalability. S7 – 300 is used for both simple control tasks and complex automation systems.

Web server implementation on Simatic S7-300 is done using Web2PLC tool. For that purpose, it is necessary to go through several steps [3]:

- Configuration of S7-300 station:
 - Hardware configuration,
 - Creating Symbolic Names,
 - Exporting symbols, project settings and enumerations,
- Creating HTML document,
- Generating projects settings,
- Creating S7 code solution,
- Starting web server and accessing web site.

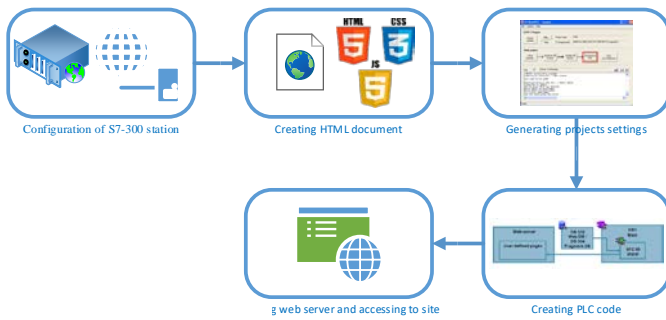


Fig. 3. Steps for implementation web server in PLC S7-300 [9].

A. Configuring S7-300 station

Configuring an S7-300 station involves setting up the hardware and software components of the system to ensure that it performs the desired functions. In this case hardware components are already connected in PLC rack. In the STEP 7 software, it is needed to configure the hardware components by adding modules (described in section III) and assigning them to specific slots. After connecting the programming cable from the computer to PLC programming port Simatic STEP 7 software is being run. After creating the new STEP 7 project, it is necessary to do a hardware configuration, which includes configuration of all station modules. The important part is setting the Ethernet interface. It is needed to add a new interface and assign the IP address of the CPU to the Ethernet interface. Next step is enabling web server on PLC and adding users in hardware setting of CPU on Web tab. Adding users is necessary to protect against unauthorized access [3].

Once the hardware components have been configured, symbols can be created in the symbol file to represent the physical inputs and outputs of the system. In the project tree, after clicking on "Symbol Table" new symbols can be added by entering symbol name, data type, and physical address. This can make programs easier to understand and modify, as users can refer to the symbols instead of the raw addresses of the inputs and outputs [3].

The last step in configuration of S7-300 station is exporting symbols, project settings and enumerations with S7-Web2PLC. S7-Web2PLC is software tool which is developed to enable remote monitoring and control of Siemens PLC systems, in addition, S7-Web2PLC enables many functionalities for creating web-based HMIs SIMATIC S7-300 system, such as creating user-defined HTML web pages and remote access possibilities. By right clicking on "Block Holder" S7-Web2PLC is opened and a new project is created. After clicking on "Export Symbols" all symbols are ready to use in HTML file [3].

B. Creating HTML document

HTML stands for Hyper Text Markup Language and is used for creating web pages. HTML consists of a set of markup tags given in Table I, which are used to define the structure and content of a web page. HTML tags are enclosed in angle brackets and consist of a tag name and attributes.

TABLE I
COMMONLY USED HTML TAGS

Tag name	Description
<!DOCTYPE>	Define document type
<html> ... </html>	This tag marks the beginning and end of an HTML document.
<head> ... </head>	This tag is used to contain the metadata of the web page, such as the title and links to external files.
<body> ... </body>	This tag is used to contain the visible content of the web page.
<h1> ... </h1> <h2> ... </h2> ... <h6> ... </h6>	These tags are used to define headings of different levels, with <h1> being the largest and most important heading.
<p> ... </p>	This tag is used to define paragraphs of text.
	This tag is used to define a image.
<table> ... </table>	This tag marks the beginning and end of a table.
<a ... 	This tag is used to create hyperlinks to other web pages or resources.

To send data from an HTML to PLC, a user can define a form in HTML with input fields for the data they wish to send. When the form is submitted, the data is sent to the server using the POST method, which then sends the data to the PLC using the appropriate communication protocol.

In principle, HTML is static page and if values changed in PLC that is not immediately reflected on the HTML page, the page may need to be refreshed to display the updated value. Some of ways to refresh page is [3][9]:

- Manual refresh - refresh button that can be clicked to reload the page and get the latest content,
- Refreshing with HTML - using HTML meta tag with attribute *http-equiv="refresh"*,
- Refreshing with JavaScript - creating a script that uses AJAX to periodically update the HTML page with the latest values from the PLC without requiring a full-page refresh. This way used in this solution.

For sending data to PLC or Displaying variables from the CPU on the web page we need to use "user-programmable web pages" (germ. *Anwenderprogrammierbare Webseiten* - AWP) and command names shown in Table II.

TABLE II
AWP COMMANDS WITH DESCRIPTIONS

Tag name	Description	Example
:= "<Name>"	For showing value of variable	:= "TankLevel":
<!-- AWP_In_Variable Name =" "<Name>" -->	For Writing value of variable	<!-- AWP_In_Variable Name="OpenValve" -->
<!-- AWP_Enum_Ref Name=" "<Name>" Enum=" "<Variable> " -->	For showing enumerations	<!-- AWP_Enum_Ref Name="Alarm" Enum="AlarmValue" -->

C. Generating Project Settings

When HTML file is created, we need to add file location in S7 Project settings. Also, if we have enumerations, we need to insert enumerations in "Enum Types" tab. After that we are go

on generating, compiling and download code to CPU according to Fig 4.

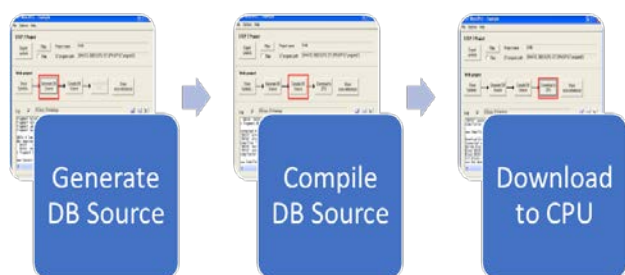


Fig. 4. Steps for uploading code to CPU.

D. Creating S7 code solution

PLC programming is based on correspondence between data and function blocks. Both types are fundamental and data blocks store all required data for program execution (parameters, variables etc.). Fundamental blocks for creating PLC web server are DB33 and SFC99. DB333 is one of the integrated blocks in the S7-300 PLC system and it is used to store and process necessary data. And this block is connected to the SFC99 (also known as www block). Calling the SFC99 block initializes the web server on the controller processor. By cyclically calling the block, we enable all changes of processor variables to be visible on the web page. Block diagram of S7 program structure is on Fig. 5.

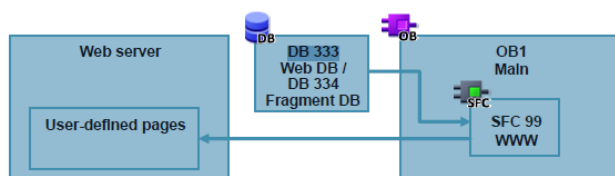


Fig. 5. Block diagram for S7 program [10].

E. Starting web server and accessing to web site

Once the program is uploaded to the PLC, it calls SFC99 block and web server has been initialized. During the configuration, the IP address is assigned to the S7-300 PLC. This local IP address is translated into a public IP address which is used to access web server from any device via web browser.

There are two types of web pages that are available; default web pages generated by software and user – defined web pages. Examples of default web pages are given in Fig. 6. Views of login and start page are shown. Access, thus monitoring and control of proper system is secured, and all users must have username and password.



Fig. 6. View of login and start web pages.

User – defined web pages are those generated from user HTML file. They are customized to the system's purpose and user's needs. View of custom defined pages for simple system is shown on Fig. 7. Two different states of system's digital inputs and outputs are given.

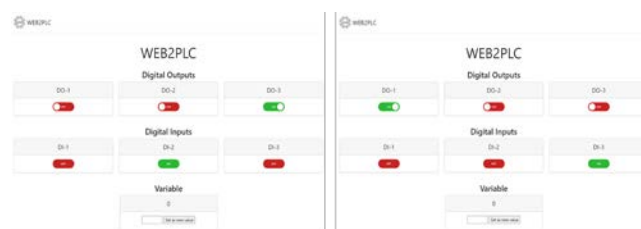


Fig. 7. Views of user – defined web pages

IV. REMOTE PLC PROGRAMMING

In current practice, PLCs are programmed using different PG/PC interfaces which usually require physical connection. Today, the need to execute tasks and actions remotely is becoming more and more common. Public IP address could be assigned to Simatic S7 300 station, so it can be accessed remotely from any web browser. This IP address could also be used for remote programming of the above PLC.

For communication between S7 300 station and programming station it is possible to use many interfaces such as MPI, PROFINET, PROFIBUS DP, Wi-Fi etc. When using network protocols, the programming tool establishes connection by local IP address which is assigned to station [8]. This allows access only from devices within the same network. However, by assigning a public address it is possible to establish a connection between the station and the remote programming device.

STEP 7 software is a development tool which enables easy programming and testing of a program. After creating the new STEP 7 project, it is necessary to do a hardware configuration, which includes configuration of all station modules. Next step is to write the program using any of available programming languages. The last step is to establish an online connection between the programming device and station, so both hardware configuration and program could be downloaded to the PLC. Connection can be established by using above mentioned interfaces [7]. In this case, it is necessary to set PG/PC interface using Wi-Fi adapter. Target station address should be set as public IP address of the station. Once the connection is established, it is possible to upload a program, test it and correct potential errors.

This approach expands possibilities in PLCs programming and enables remote work. It can be used in educational and training purposes, as it does not require physical presences. It can also be used in industry if it is necessary to make changes to the already installed system.

On the other hand, this approach is in the early stages of development because it has some security problems; anyone can access a certain station, by accident or intense. So, it is necessary to improve this approach by posting some kind of firewall. It can be done by managing access only at specific time and from specific networks and devices. This is planned to be done in future work.

V. CONCLUSION

Human Machine Interfaces represents indispensable tools in systems with programmable logic controllers. These graphical interfaces are used by operators for simple and functional control and monitoring of PLCs systems. They need to be user – friendly and easy to use.

Today, the presence of web technologies in industry and automation control enables design and utilization of web-based HMIs. These HMIs offer significant performance improvements, and they have many advantages such as remote access and control, flexibility, and scalability. This approach is becoming more and more present.

In this paper, the technology behind web-based HMIs is described through implementation of web server in a specific PLC system. For this implementation software tool S7-Web2PLC is used along with couple of data and function blocks. Implementation is done in several steps, as all necessary hardware and software components need to be configured. This approach enables generation of user-defined web page which represents web-based HMI, so it is possible to access and control system remotely and in real – time. Using the tools mentioned above makes users possible to create their own HMIs for different applications in industrial automation.

In addition, the approach of remote PLC programming is described in this paper. Connection is established by public IP address assigned to the PLC. Once the connection is

established, it is possible to upload a program, test it, and monitor its execution. However, this is at the very beginning as there are some security issues that should be solved.

To conclude, web technologies are increasingly used in all aspects of industrial automation. Web – based human machine interfaces have become more common as they offer a lot of features and functionalities and have many advantages over traditional once.

REFERENCES

- [1] W. Bolton, *Programmable Logic Controllers*, 4th ed. Oxford, UK, Elsevier Newnes, 2006.
- [2] T. Lojka, P. Šatál, J. Mocnej, I. Zolotová, “Web Technologies in Industry HMI”, IEEE 19th International Conference on Intelligent Engineering Systems, Bratislava, Slovakia, pp. 103-106, September, 2015.
- [3] Siemens, “Visualization with User-defined Web Pages – S7-Web2PLC”, Application description, November 2010.
- [4] P. M. Steib, “Web technology in automation”, Whitepaper, Saia-Burgess Control, 2009.
- [5] Shyr-Long Jeng , Wei-Hua Chieng, and Yi Chen, “Web-Based Human-Machine Interfaces of Industrial Controllers in Single-Page Applications”, April, 2021
- [6] Siemens Industry Mall, S7 – 300, Accessed: 10. 4. 2023, <<https://mall.industry.siemens.com/mall/en/ww/catalog/products/5000013#Overview>>.
- [7] C. T. Jones, *Step 7 in 7 steps*, 1st ed. United States of America, 2006.
- [8] Siemens, “SIMATIC S7-300”, Germany, 2011.
- [9] Siemens, “Simple Examples for the Web Server of SIMATIC S7-1200/S7-1500”, August 2015