Node-RED for PLC Automation

Daniel Ribeiro de Sousa and Vitor Mendes Caldana
Federal Institute of Sao Paulo (IFSP) – Sorocaba Campus
Sorocaba, Sao Paulo, Brazil
Daniel_21Sousa@outlook.com; vitor.caldana@ifsp.edu.br

Abstract

Industry 4.0 is rapidly changing how we view the world around us and it has been pressuring the Industry to develop new solution with several new concerns. However, in some industrial regions and countries, the presence of old systems (Legacy Systems) is very common and there is not enough money to make the necessary upgrades by changing all the installed hardware. To adapt the existing structure to Industry 4.0 several researchers have been experimenting with Node-RED and OPC-UA. In this study, we will propose a model and present Node-RED flows to achieve Industry 4.0 capabilities on S7-300 SIEMENS PLCs on a PROFIBUS network. As we finish this experiment, we conclude that the solution is possible but further research and implementation is still needed to accomplish the goals of bringing the Legacy systems to Industry 4.0

Keywords
Industry 4.0, Node-RED, OPC-UA, Legacy Systems, Industrial Automation

1. Introduction

The first industrial Revolution on the XVIII century transformed production: from manual labor to power driven solutions. This new concept of production stablished a new Revolution not only in the industry, but in economy, increased productivity and also shaped a new form of relationship in our society. As the decades passed, society looked for new ways to make the industry more efficient, introducing steel, electricity, oil-derivative fuels, electronics, computer systems and automation of the production process. (Sakurai & Zuchi, 2018; Schwab, 2018; Silva et al., 2021)

Today the industry is facing high demands that require the improvement of the production process, in all scales, from communication with suppliers to product sales. These requirements are becoming more specific and complex as the customization of the final product is in high demand.(Löcklin et al., 2020; Tao et al., 2019)

However, each economic and industrial revolution bring new challenges and sets new approaches within the organizations. Companies that wish to journey in the trajectory of Industry 4.0 must evaluate their capabilities and adapt their strategies in a way to implement them on the appropriate scenarios. (Almeida & Pinheiro, 2022; Santos et al., 2018)

New technologies will reshape the production processes through integration between the industrial automation on the factory floor (PLC´s and similar devices) to the corporate level communication and from commissioning to operation. One of the initiatives of Industry 4.0 is the implementation of internet (and also IIoT – Industrial Internet of Things) to make available signals and information that comes directly from the factory floor. (Cheng et al., 2015)

As an alternative for this transformation of the industrial plants, knowing that there are several Legacy systems and old PLC´s without the capability of integration needed by the Industry 4.0, the utilization of technologies such as Node-RED and OPC-UA that combined with the existing networks of PROFIBUS and other older protocols can be able to “upgrade” these systems from the 3rd industrial revolution into Industry 4.0 specifications. (Ferencz & Domokos, 2019)

1.1. Objectives

The objectives of this paper are to better understand how Node-RED can be a “translation” tool that enables the Legacy systems PLC´s to communicate via internet to other Industry 4.0 devices using OPC-UA. To accomplish this, the paper will focus on two main areas:

a) Construct a base of knowledge to better understand the existing communication protocols, Node-RED and OPC-UA.

b) Build test flows on Node-RED that would communicate with a S7-300 SIEMENS PLC and make the information available in OPC-UA for other instances to access them.

2. Literature Review

To follow is the necessary literature review to achieve the objectives described in section 1.1. The method used was the “integrative review” that revises, investigates and comprehend different studies, unifying them towards creating a solution for the problems and objectives of the work.

2.1. Node-RED

Node-RED was developed by IBM (OpenJS Foundation & Contributors, 2013) as a side project of the companies initiative to develop technologies based on services. Based on Node.js and MQTT (Message Queuing Telemetry Transport), the language is based on Flows of information is displayed on web browsers. As it uses JavaScript it does require deep knowledge of HTML and CSS for the user dashboard screens. One of the main features of Node-RED is that is an Open Source solution, which increases the number of applications developed using this tool as it only requires a web browser and does rely on proprietary software of expenses licenses that would make mass use improbable.

The rapid use in IoT (Internet of Things) can be explained by the features listed above, however on the IIoT scenario there are still restrictions and obstacles that need to be removed, and they are mainly the use of Open Source code and the security related issues. Another relevant issue is the lack of standardization, as a particular need can be solved in multiple ways with different Nodes and Flows and this particular issue have been noted by the Node-RED community and also been addressed by researchers, such as the work of Clerissi et al. (2018), seeking a stable and robust solution for development.

Nevertheless, with the advent of Industry 4.0 and its data driven nature, Node-Red has gained some space as the proposed structure is very flexible and easy to adapt. (Gouveia, 2021). Several studies and research have been conducted in recent years in several segments of industry where Node-RED is presented as the tool for Industry 4.0 (even though most of the are still in the simulation and concept phases). These studies integrate Node-RED with other protocols and services on several different industry sectors, from voice-activated home automation (Rajalakshmi & Shahnasser, 2017) to industrial applications (Ferencz & Domokos, 2019; Nițulescu & Korodi, 2020).

2.2. OPC and OPC-UA

The use by the industry of computer-based applications increased during the 90´s, however communication issues arose between different manufactures. To suppress this communication problem a task force was created to define a standard, dubbed OPC (Open Platform Communications), that was easy to implement, use and maintain by multiple suppliers allowing a standard access to the automation data over Windows. The resulting work was published by the OPC Foundation with the “Classic” version being based on COM e DCOM to integrate existing industrial protocols, such as Modbus and PROFIBUS, to the existing SCADA (Supervisory Control And Data Acquisition) systems. (OPC Foundation, 1996),

With the success of the OPC protocol, another instances and variations of them where released such as the OPC-UA (Unified Architecture), to create a replacement, keeping original specifications, performance and covering all the new requirements for interfacing with independent systems, risk modeling and complex systems (Mahnke et al., 2009).

2.3. The Publish/Subscribe Architecture and MQTT

The Publish-Subscribe is a model for a communication system that comprehends 3 different rolls for the devices in the network as shown in Figure 1 below:

- Publisher: The device that has the information and sends it.
- Message Broker: The intermediary device, that receives the information from the Publisher and sends it to the devices that subscribed to receive updates from that specific data.
- Subscriber: Any device that wants/requires an information. The device will send a request to the Broker to be updated whenever new information is available.

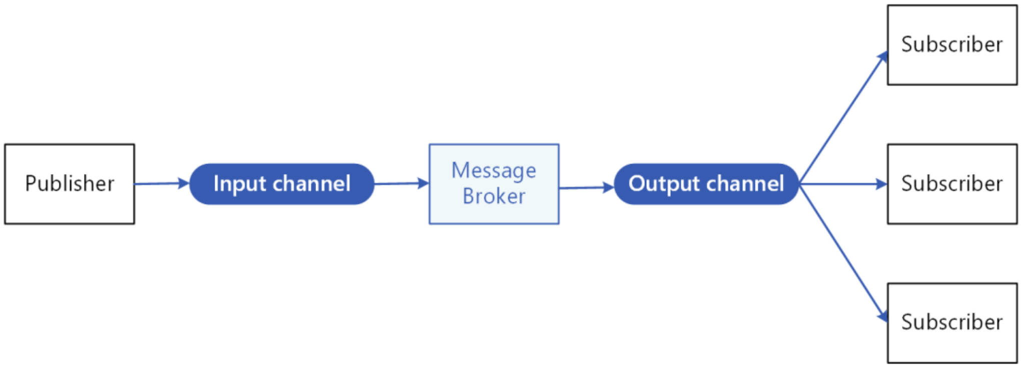

Figure 1. Publish/Subscribe Architecture (Microsoft, 2023)

This method of communication has some interesting features, such as the fact that the end-user (subscriber) and the host (publisher) do not have a direct connection and the flow of information is independent, as only the Broker knows all the network. MQTT also has less usage of data than HTML. The system also supports devices with both Publisher and Subscribe rolls, such as an air-conditioning unit with a temperature sensor that send the signal out as a publisher and subscribes to an information about temperature settings to turn on and keep a specific temperature. (Valente, 2022)

MQTT is a machine-to-machine communication protocol that focus on IoT over TCP/IP and uses the Publish/Subscribe architecture describe above. MQTT with OPC-UA and Node-RED provide a complete solution that allows a lightweight protocol (MQTT) with a message format standard (OPC-UA) and an open-source end-user interface based on Node.js. (Grönholm, 2023)

2.4. PLC Communications – Modbus and PROFIBUS

Modbus was created in 1979 by Modicom, so that PLC´s would be connected in automation systems. The first version of the protocol (RTU) was an open protocol that could be freely implemented in any device, becoming very common in the industry. The protocol allows for data transmission and has defined addresses based on TCP/IP. It uses the Master/Slave architecture in which the master of the network will request information from its slaves. The communication can be asynchronous, and the parameters are set in both Master and Slave devices. Older versions support RS-232 and RS-485 however nowadays TCP/IP is the most used solution with Modbus. (Cordeiro, 2019; Tabaa et al., 2018)

PROFIBUS was developed in Germany in 1987, also being open access, and is maintained by the PROFIBUS and PROFINET International. The protocol is vastly used in field instrumentation and PLC communication. It uses the OSI model and is divided in three different categories: DP (Decentralized Peripheral), PA (Process Automation) and FMS (Fieldbus Message Specification). It uses RS-485, Fibre Optics or IEC 61158 (Profibus International, 2023).

Even though both protocols now use TCP/IP and a Master-Slave configuration that are differences between them, with Modbus being easier to implement and support over modem and PROFIBUS having a more robust physical layer, a standard output and diagnostics from the instruments, an intrinsically safe installation and the ability to communicate with analog devices. (Cordeiro, 2019)

3. Proposed Model

To test the usage of Node-RED and OPC-UA as a tool for Legacy PLC systems, a structure similar to the one proposed by Abdelsattar et al. (2022) was used, comprising of a FESTO FMS (Flexible Manufacturing System) system running SIEMENS S7-300 PLCs and 7 stations connected via PROFIBUS. The Master of the network also has an Industrial

Ethernet card that would allow TCP/IP (and thus Node-RED) communications. To test the feasibility of the project only one of the slave stations was selected – Processing Station (Profibus Address 60). Details of the layout of the logical architecture can be found in Figure 2 below.

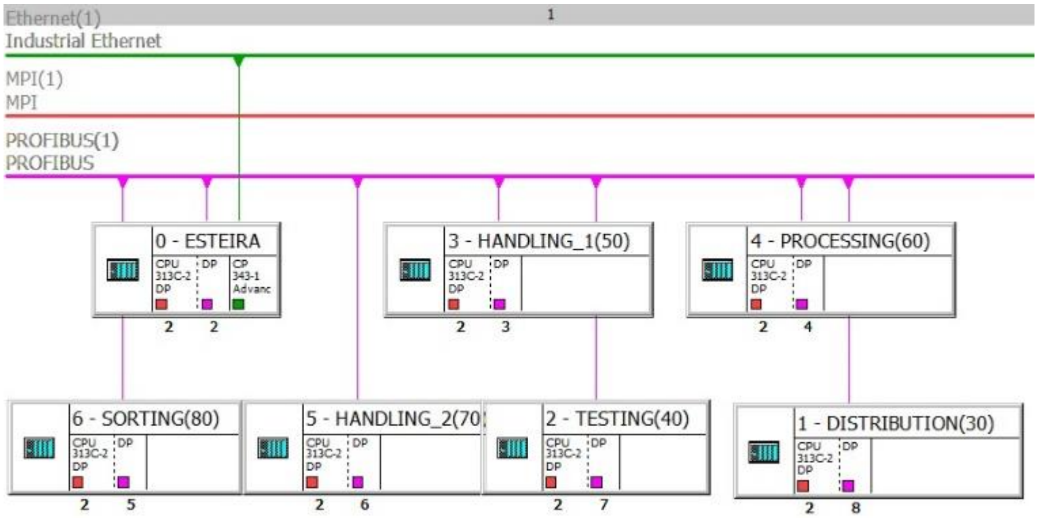

Fig. 2 – FESTO FMS Network

To connect to the PROFIBUS system, version 3.0 of Node-RED was installed on a Windows 10 laptop, including the necessary Nodes for communicating with S7 SIEMENS PLC´s and OPC-UA. The existence of this nodes that if not present would require a heavier coding process is one of the advantages as listed on the literature review. After installing Node-RED several flows were created to set up the OPC Server, the communication with the PLC and the data management for both Inputs and Outputs of the selected station. Details of the flows are described in section 4.

4. Proposed Node-RED Flows

In this section we will detail the flows created for both the OPC-UA Server on Node-RED and the station related flows for the PLC.

4.1. OPC-UA Server

The OPC-UA was created using the node mentioned on section 3. After that the variables from the station were declared, both Input and Output ones. Following what was described by Clerissi et al. (2018), a modular structure was already created, in which future works will be able to expand the idea set here for the full FMS. Figures 3 (variables) and 4 (OPC-UA Server) below show the result of the programing.

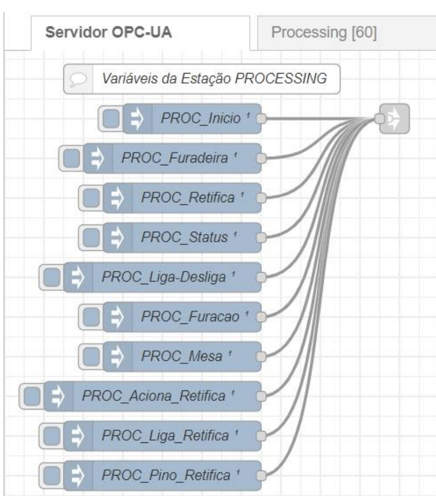

Figure 3: Variables.

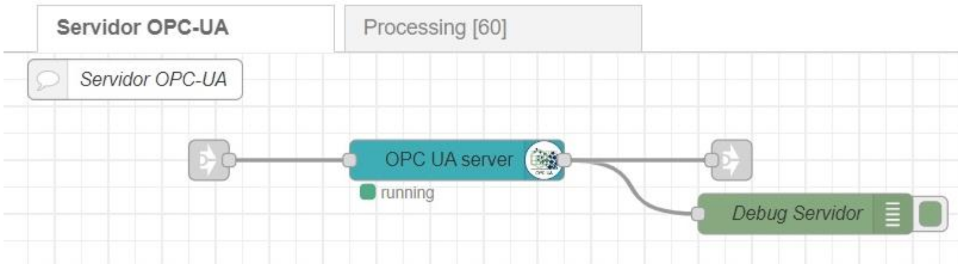

Figure 4: OPC-UA Server

4.2. Processing Station Flows

Programming the stations was divides into steps, or processes. This was done to ensure traceability and easy maintenance and commissioning of the flows. The structure created was also developed with the next steps of this research in mind, where all the stations should be programmed. Thus, a flexible and modular approach was taken, with the inclusion of an OPC-UA Client, which was necessary to visualize the variables on third party computers and mobile phones and not only on the host OPC-UA Server/Node-RED laptop.

The first step, as display in Figure 5 below, was the declaration of variables and setting the initial values by writing those on the OPC-UA Client.

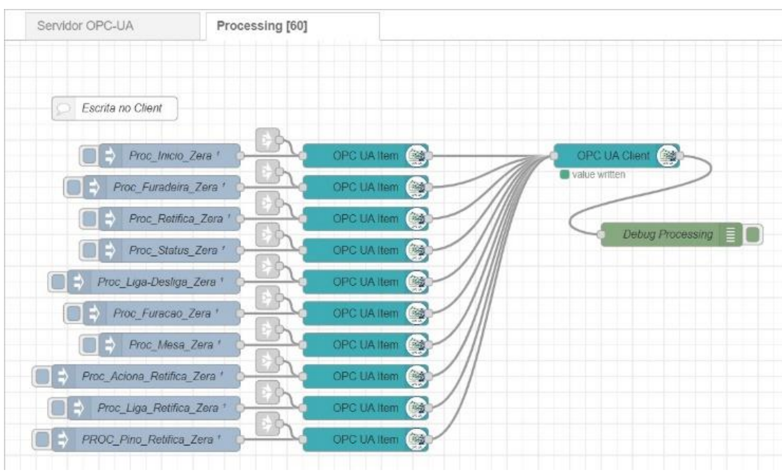

Figure 5 – Declaration and Initialization of Variables.

The second step was to create both input, as shown in Figure 6, and outputs, as shown in Figure 7, according to the data from the PLC. To be able to write the variables a function was used to translate the messages from OPC-UA to "True" and "False" that would be understood by the Ladder diagrams on the PLC.

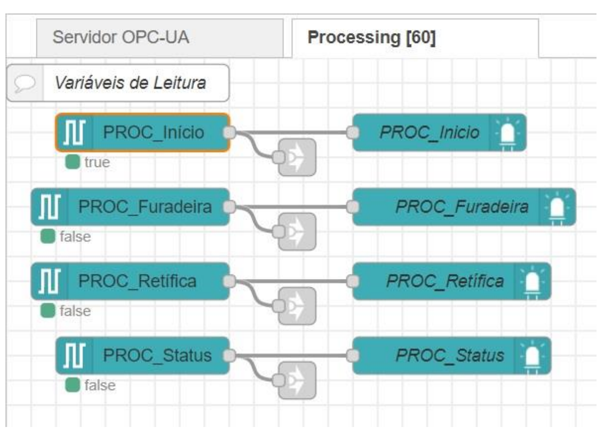

Figure 6 – Input Variables

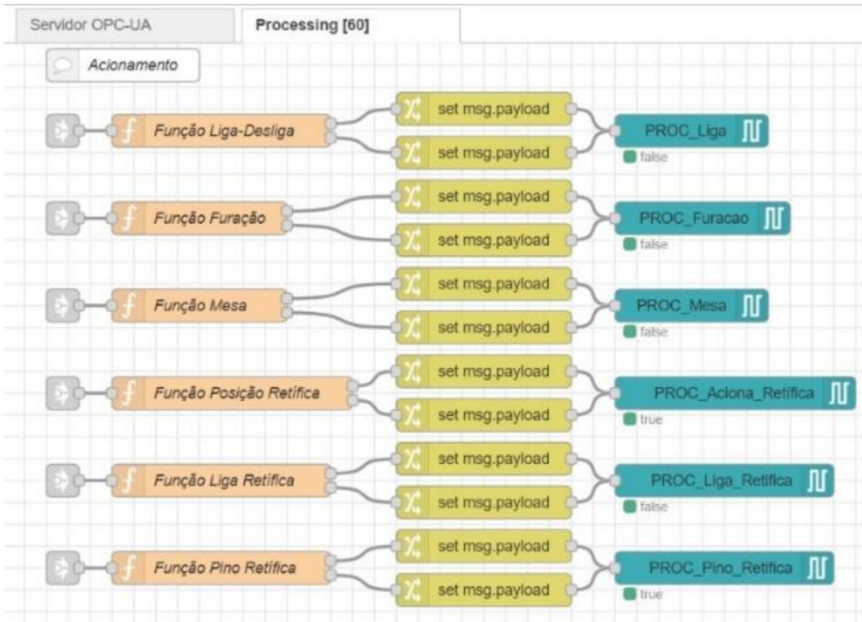

Figure 7 – Output Variables

The last part was programming the Dashboard so the information could be monitored and controlled not only on the Node-RED server laptop but any other computer on the network. For this step we would not only read the output variables of the PLC (as displayed by the LEDs on the Dashboard) but also write values of "True" and/or "False" for the input variables in the PLC. The Dashboard Commands (Figure 8) and the test dashboard (figure 9) are shown below:

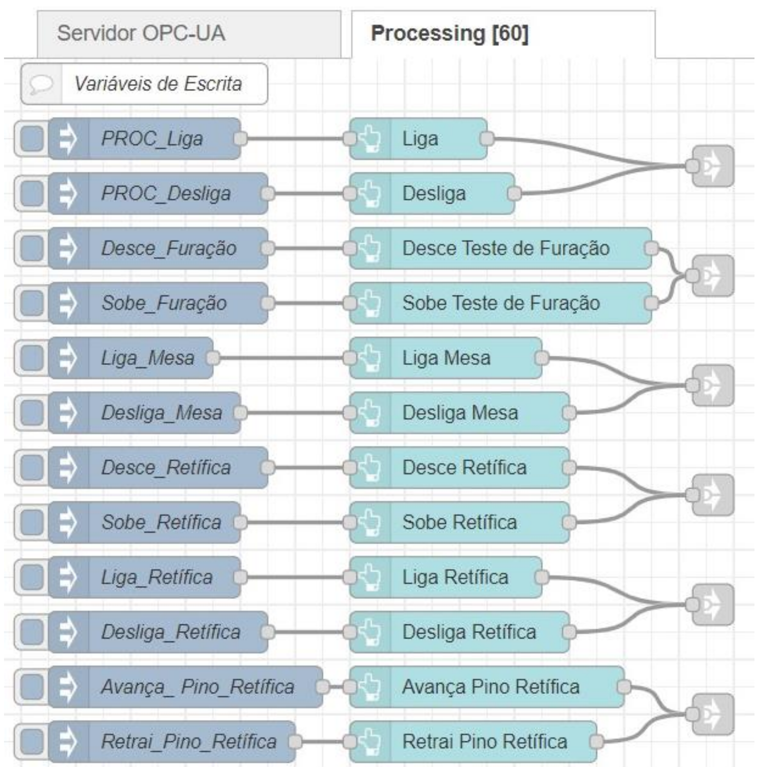

Figure 8 – Dashboard Commands

Figure 9 – Dashboard

5. Test Results

To test the feasibility of using Node-RED with OPC-UA on the FESTO MPS system, before the connection was made to the SIEMENS S7-300 PLC the structure of the database as well as the connections between OPC-UA server and OPC-UA clients were verified. To achieve this, an OPC-UA software (in this example we used UaExpert), was connected to the Node-RED laptop and the variables of the Processing station were mapped. This "software only" test allowed us to make sure the Node-RED and OPC-UA were functioning properly and allowed us to stablish that the proposed software did communicate well through the network, with information being accessed in multiple stations as it is required by Industry 4.0. Details of the test are showed if figure 11 below.

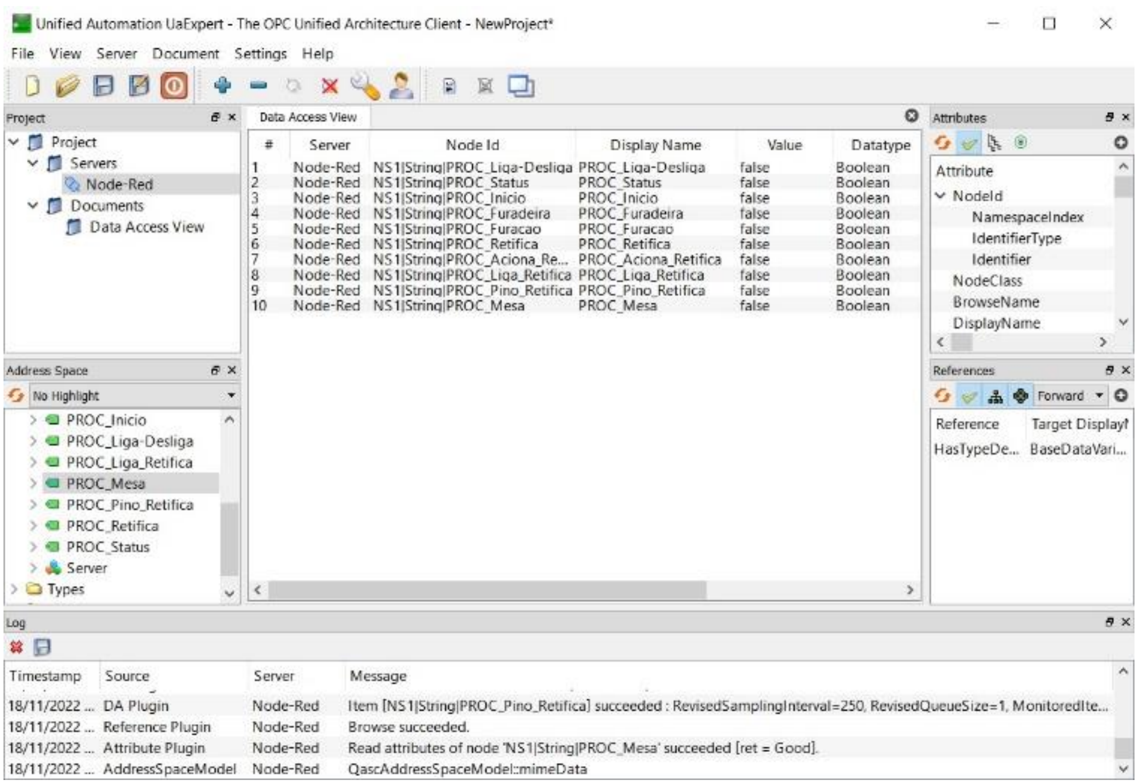

Figure 11 –OPC-UA Client Monitoring PLCs I/Os

After the software test, the solution was then implemented on the FESTO MPS system as described in section 3. Communication between Node-RED and the S7-300 PROFIBUS Master PLC was obtained by the Industrial Ethernet network. Some programming on the Master station was required to gather the necessary information from the Processing Station but it was mainly exchanging information as Node-RED could not access the station itself relying only on the PROFIBUS Master to gather all information. This particular result shows a limitation of the solution Node-

RED/OPC-UA solution, as there will be need for reprograming in all the PLC stations to make sure that all I/O´s are also mapped in the Master PLC.

Nevertheless, all tests were successful and it was possible to change the status of the actuators and read the input sensors of the Processing Station in real time in multiple computers, with different configurations on information in each (we purposefully configured different variables in different UaExpert stations) as well as all the information being present at the OPC-UA Server and Dashboard.

6. Conclusion

Throughout the process of this research, we were able to acquire knowledge on Node-RED, OPC-UA, MQTT, Industrial Communication Protocols (particularly PROFIBUS) and the multiple uses they have in the development of the industry. We looked at several case studies and research papers that ended not being included in this particular article but were used to increase our overall knowledge on the subjects. The literature review was ample enough to achieve objective a) as detailed in section 1.1 and the researchers mark it as complete and successful.

The development of the Flows for Node-RED was particularly challenging. As described by several authors, and particularly as outlined by Clerissi et al. (2018), there was great concern in making the software easy to use, easy to maintain and easy to upgrade as this is only the first step of a bigger research project. With the proposed modular structure by station, and the division in Node-RED of Server and Clients, we believe this objective was also achieved successfully.

Finally, we were able to field test the proposed model on the FESTO MPS system, being able to send signals to the PLC via the dashboard of Node-RED and receive the necessary feedbacks. The process took a few tries and there was some learning in the failed attempts that ultimately led to a fully functional Processing Station communication. Once that was concluded objective b) outlined in section 1.1 was also conclude and marked successful.

Future work for this project will include a full mapping of the FESTO MPS system and a complete reprogramming of the stations, allowing the integration of each single process as a service for better implementation and flexibility of the plant as needed by Industry 4.0

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Biography

Daniel Ribeiro de Sousa is currently a student in the Electronics High-School Technical course of IFSP Sorocaba Campus, starting in 2021 and with graduation due in 2024. He has worked with Prof. Dr. Sérgio Shimura in 2021 on an extension project to instruct teachers at elementary schools of the city of Porto Feliz in microcontroller programming based in Arduino and since 2022 is working with Prof. M.Sc. Vitor Caldana in the Node-RED for PLC Automation research project.

Vitor Mendes Caldana began his career with a technician course in Electronics from Liceu de Artes e Ofícios in 1999, followed by an undergraduate degree in Electronic Engineering from Universidade Presbiteriana Mackenzie in 2004. In 2016, finished his M.Sc. in Industrial Engineering with Quality of Engineering Education and its Relation to Regional Development as his area of research. As a technician started in 1999 in a service-based company in Brazil that represented American and European automation proprietary equipment for the printing industry, serving Brazil and South America, with services performed also in USA and China. During his professional career took several courses in Brazil as well as USA and Europe in Automation, Project Management and proprietary equipment maintenance. In 2014 began his teaching career in FIEB as a substitute teacher, followed by an associate professor position for the Technical Course of Electronics. In 2016, whilst holding a position Service and Project Manager decided to become a full-time professor and left the industry and FIEB to join IFSP, moving to the Sorocaba Campus to implement the Electronics High-School Technical Course. In 2018 started the Research Group in Industry 4.0 at IFSP and has been its leader since. Between 2019 and 2020, along with his colleagues, designed and implemented the first Post-Graduate Program in Industry 4.0 of IFSP at the Sorocaba Campus. He is currently involved in research projects in Industry 4.0.