



**HAL**  
open science

# How to apply digital function interconnection requirements into a SCADA environment for Industry 4.0?

Pascal Vrignat, Christophe Charrière, Manuel Avila, Florent Duculty,  
Stéphane Begot, Jean-Christophe Bardet

## ► To cite this version:

Pascal Vrignat, Christophe Charrière, Manuel Avila, Florent Duculty, Stéphane Begot, et al.. How to apply digital function interconnection requirements into a SCADA environment for Industry 4.0?. IICE, Apr 2024, Dublin ( virtual ), Ireland. hal-04536535

**HAL Id: hal-04536535**

**<https://hal.science/hal-04536535>**

Submitted on 8 Apr 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# How to apply digital function interconnection requirements into a SCADA environment for Industry 4.0?

Pascal Vrignat<sup>a\*</sup>, Christophe Charrière<sup>a</sup>, Manuel Avila<sup>a</sup>, Florent Duculty<sup>a</sup>, Stéphane Begot<sup>a</sup> and Jean-Christophe Bardet<sup>a</sup>

<sup>a</sup> Univ. Orléans, PRISME, EA 4229, F45072, Orléans, France

\*Corresponding author: PRISME Laboratory, MCDS Team, University of Orleans, 2 av. François Mitterrand 36000 Châteauroux, France. Email: pascal.vrignat@univ-orleans.fr

## Abstract

*This work presented consists of automatically managing a real process based on different manufacturing recipes. The data is routed over a digital network (Local Area Network) and encapsulated in an OPC UA protocol. The homothetic process is a chemical system consisting of different baths for surface treatment of metal objects. Recipes can be loaded automatically from Excel files. Each Excel file has been adapted with a script in Visual Basic for Applications (VBA). The various recipes are available in read-write format. Under these conditions, the process manager can process all data in an adapted human-machine interface solution. The control system is managed by a Schneider Electric PLC (Modicon M340). The program embedded in the PLC is developed in the EcoStruxure Control Expert software environment (CEI 61131-3). This 28-hours assignment is for 2nd year Bachelor students. It responds perfectly to the current needs of industry. In this context, students can acquire new skills in the context of the connected factory and in a Supervisory Control and Data Acquisition (SCADA) environment. A specific collaboration with a software publisher (Skynet) and our University enables the use of a client/server gateway for OPC UA protocol. This official partnership agreement allows our University to use a software package that is normally very expensive, but which is totally free under these conditions.*

## 1. Introduction

The work presented in this paper outlines a project validated with students in their second year of a bachelor's degree program in Electrical Engineering and Industrial Computing (28 hours' work). This technical endeavor is integrated into a Project-Based Learning methodology [1], [2], [3]. The technical objectives to be validated are numerous and demanding:

- Provide a contextualization of the "Surface finishing" function within a real industrial context.

- Examine the "Surface finishing" system proposed in this work, encompassing its control and operational components.
- Develop a model of the system utilizing functional analysis and an "Octopus" type diagram.
- Justify specific technical choices and propose alternative approaches capable of fulfilling the same function and requirements.
- Identify components depicted on the electrical diagram of the system.
- Analyze the existing program and adapt it to align with the new operational requirements.
- Perform tests to validate the new program. This new program can be implemented using various strategies (SFC, LD, ST, FBD [4]). Provide a comprehensive verification strategy (coherent checklist) for this purpose.
- Identify and map the architecture of the industrial network being utilized.
- Capture and analyze data accessible via the PLC on the OPC UA communication channel [5].
- Research and develop a "Traceability (Reporting)" solution tailored for the manager of the "Surface treatment" line within an Excel environment (OPC UA client).
- Investigate and develop a solution for managing manufacturing recipes catered to the "Surface finishing" line manager within an Excel environment (OPC UA client).

This project encompasses several technical resources:

- A "Surface finishing" homothetic system.
- Control Expert (Control-command configuration & development of the program for the PLC).
- PRONETA (network sniffer and network administration) [6].
- Advanced IP Scanner (network sniffer).
- UA Expert (Sniffer, Item OPC UA).
- OPC UA Expert Configuration (OPC UA communication channel configuration).
- Cogent DataHub (OPC UA Client/Server).
- Excel & VB Macro (OPC UA Client, development of the "Reporting" HMI traceability solution).

## 2. The technical context of work

After various research projects, the task involves formalizing a study summary to present the function within the context of real industrial needs. This formalism could be presented on a one-page A4 format. Initially, the system will represent a "Surface treatment" line for aluminum parts to be treated. Five treatment baths are available. The parts are installed on transfer bars and are moved from bath to bath by a robot. Chromating (Alodine) is a surface treatment for aluminum widely used for its anti-corrosive and electrically conductive properties, as well as its excellent adhesion to paints and adhesives. This treatment can be applied to all aluminum surfaces (Figure 1, Figure 2). Before chromating, the aluminum surface must be carefully cleaned and deoxidized. The different stages of Passivation: Degreasing => Rinsing => Pickling=> Rinsing => Chromating (Alodine) => Rinsing.

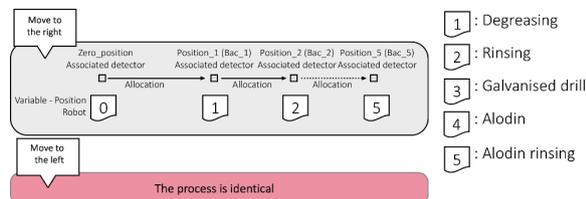


Figure 1 Simple presentation of the operating part of the system

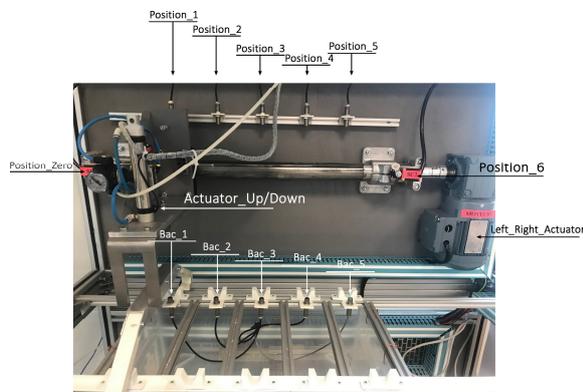


Figure 2 Position of detectors and actuators

The system has various inputs and outputs (digital). Details are given in Figure 3, Figure 4. The parts list for the various components and the various electrical diagrams for the system are available. After consulting the technical documentation of the system, this assessment emerges as one of the essential tasks that students must undertake.

Reference points / Inputs	PLC Address	Description
Bp1	%I0.2.14	BP Init = "Initial position" pushbutton
Bp2	%I0.2.15	Go up in "Manual" mode
Bp3	%I0.3.0	Go down to "Manual" mode
Bp5	%I0.3.2	Cycle "start" push-button
Bp6	%I0.3.3	Translate left to manual
Bp7	%I0.3.4	Translate right to manual
Com-Auto	%I0.3.14	Automatic operation switch
Under voltage	%I0.3.12	Undervoltage operating section
Low	%I0.2.3	Bottom bracket
Top	%I0.2.2	Top bracket
Poste_0	%I0.3.10	Carriage at station 0
Poste_1	%I0.2.6	Carriage at station 1
Poste_2	%I0.2.7	Slide at station 2
Poste_3	%I0.2.8	Trolley to station 3
Poste_4	%I0.2.5	Trolley to station 4
Poste_5	%I0.2.4	Trolley to station 5
Poste_6	%I0.3.11	Trolley to station 6

Figure 3 Inputs

Reference points / Outputs	PLC Address	Description
EV	%Q0.1.6	Mounting bracket
Kmdrive	%Q0.1.2	Switching on the drive
Kmright	%Q0.1.0	Move right
Kmleft	%Q0.1.7	Move left LED 1
H1	%Q0.1.5	Led 1
H2	%Q0.1.4	Led 2

Figure 4 Outputs

## 3. Develop a control/command function based on the real needs of manufacturers

The overarching objective of the work outlined in this subsection is encapsulated in Figure 5. This endeavor involves utilizing two files (Excel models) to fulfill present demands regarding system Control-command and traceability. Within this framework, the automatic loading of diverse settings and instructions in the form of a recipe will be executed automatically under the supervision of the production line controller [7].

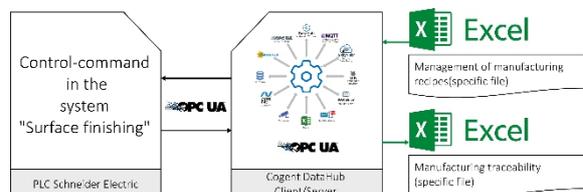


Figure 5 General system management principle

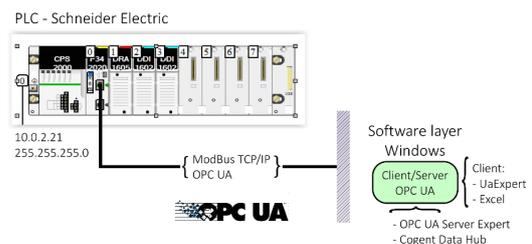


Figure 6 Layer of the communication network

Part of the industrial network architecture and the principle of communication and services are depicted in Figure 6. Students will be tasked with managing static IP addresses. Figure 7 illustrates the development that requires validation to furnish the line operator with pertinent information regarding the operation of the system (development of a Human Machine Interface). The system information is consolidated within a spreadsheet-type environment. A notable aspect of this environment is its capability to leverage a wide array of functions already implemented in libraries (such as conditional formatting, histograms, pie charts, mathematical calculations, ...).

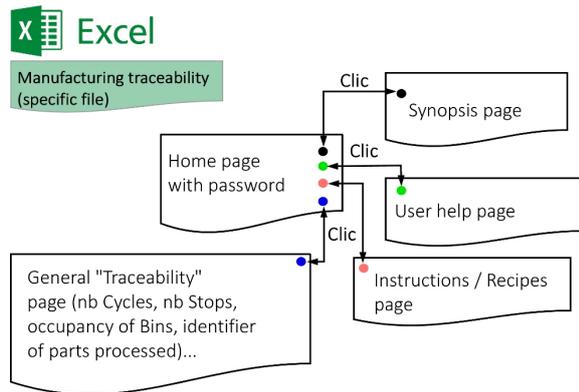


Figure 7 Organization of user pages for complete traceability of the application

#### 4. The principle of managing recipes

A basic program is provided to the students, allowing the system to operate in a precise mode while adhering to a potentially configurable manufacturing recipe. The objective of the task is to adjust different recipes on demand by specifying the required position based on the relative position of the carriage managing translations (Left-Right) and determining the soaking time delay according to the number of containers. These values must be extracted from a pre-filled table. Figure 8 outlines the general principles to be followed for modifying this program. Figure 9 (a and b) illustrates the principle of managing a table and its associated numerical values (setpoint, identifier, ...).

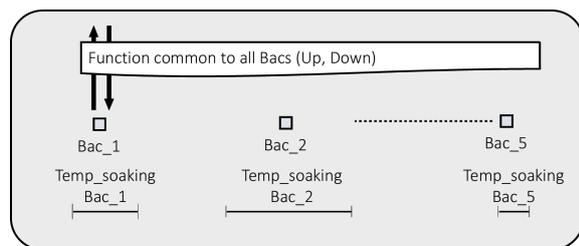


Figure 8 The general principle for managing a recipe

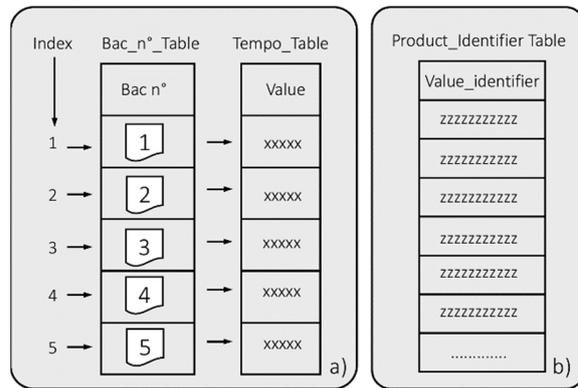


Figure 9 Principle of table management

#### 5. A few examples of results

In order to meet the technical requirements of the task, students must validate various software layers with specific configurations. This task demands a high level of rigor and thorough analysis of the digital data routed over the network. Figure 10 describe the configuration of the OPC UA access point in the “EcoStructure OPC UA Server Expert Configuration tool” software environment.

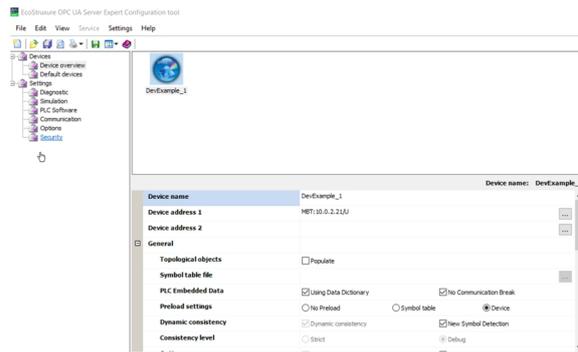


Figure 10 Configuring the OPC UA access point with the PLC

Figure 11 specifies whether it is possible to declare a certificate in OPC UA communication. This certification enables data encryption with specific key generations. No certificate will be present in your application.

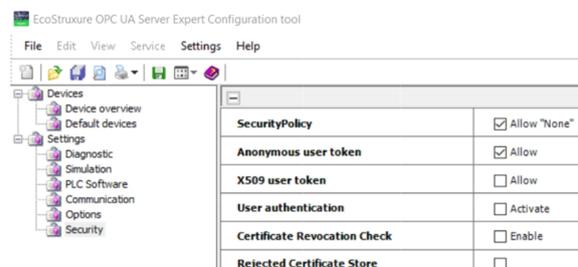


Figure 11 Configuring the OPC UA access point with the PLC

After completing the configuration, you should keep this software open. Next, launch the "EcoStructure OPC UA Server Expert" software environment. This software should automatically provide an address based on computer's static IP address (see Figure 12). If the configuration is correct, communication with the OPC UA channel of the PLC, along with the loading of its "nodes" (data), should Start (see Figure 13).

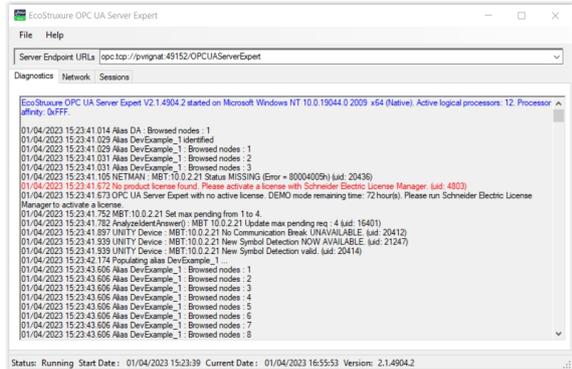


Figure 12 Configuring the OPC UA access point with the PLC

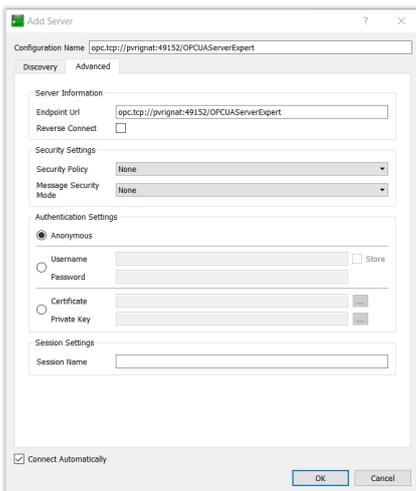


Figure 13 Declaration of the access point by the EcoStructure OPC UA Server Expert software

The EcoStructure OPC UA Server Expert environment must remain active throughout the remainder of the task. Sniffing the selected "Item" data in OPC language is crucial. This work allows for the verification of all information transmitted by the PLC. For this task, you must utilize the software UaExpert. The various configurations are provided in the figures below (see Figure 14 and Figure 15).

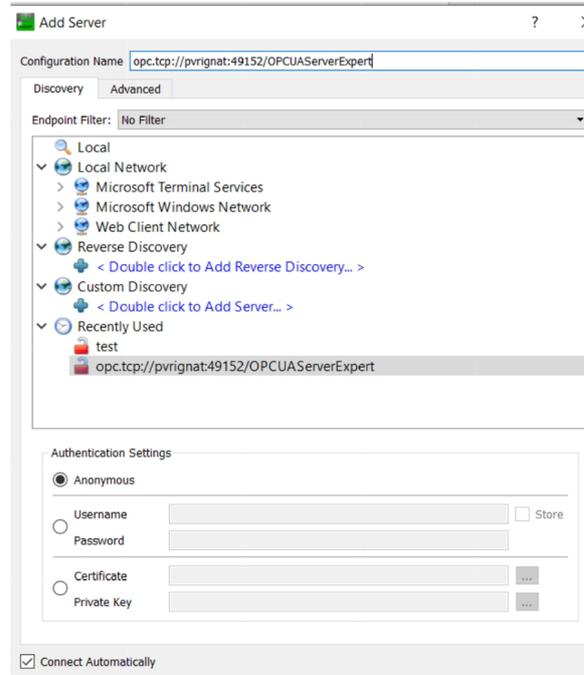


Figure 14 Configuration with the "UaExpert" software

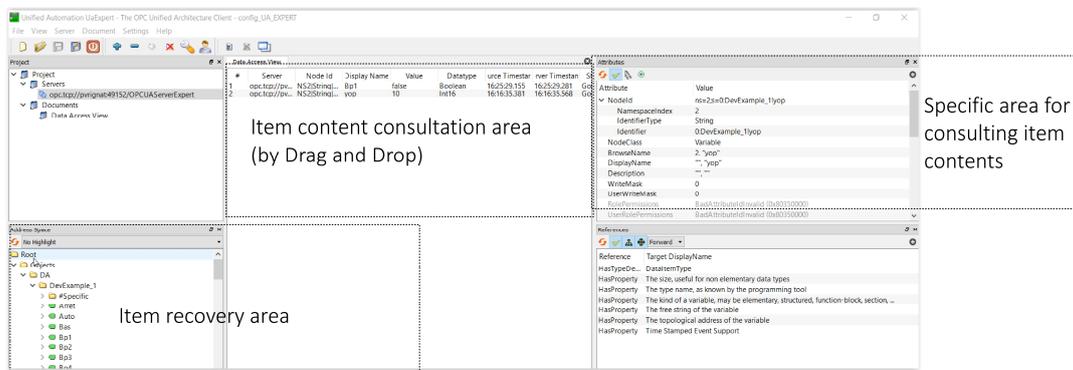


Figure 15 Verification of the data made available by the PLC in the "UaExpert" software

Cogent DataHub (OPC UA client/server (Figure 5) after its configuration allows you to retrieve all the data made available by the PLC (Figure 16). Figure 17 describes the principle of connection between Excel and Cogent DataHub.

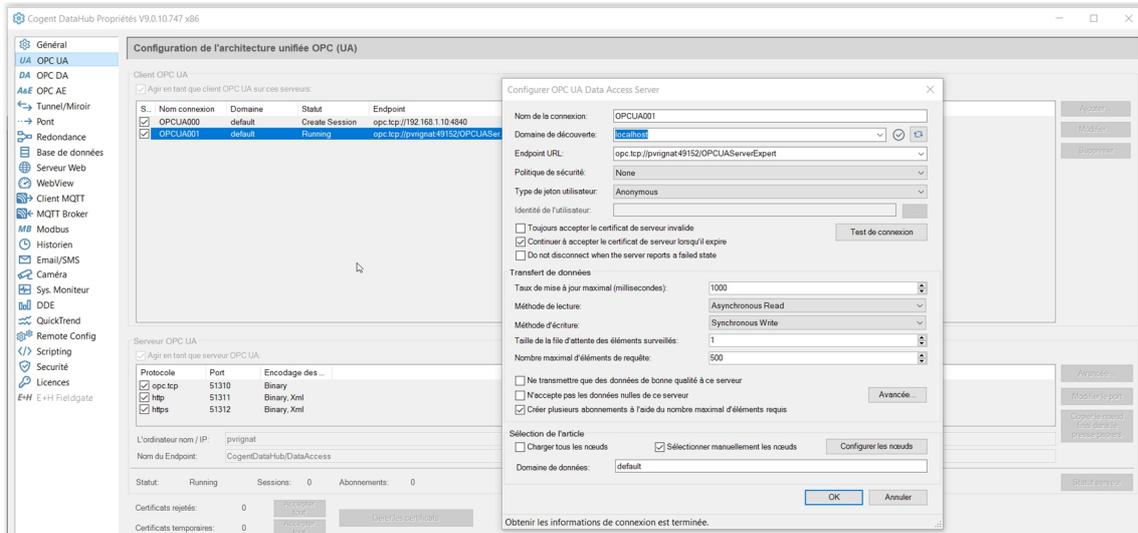
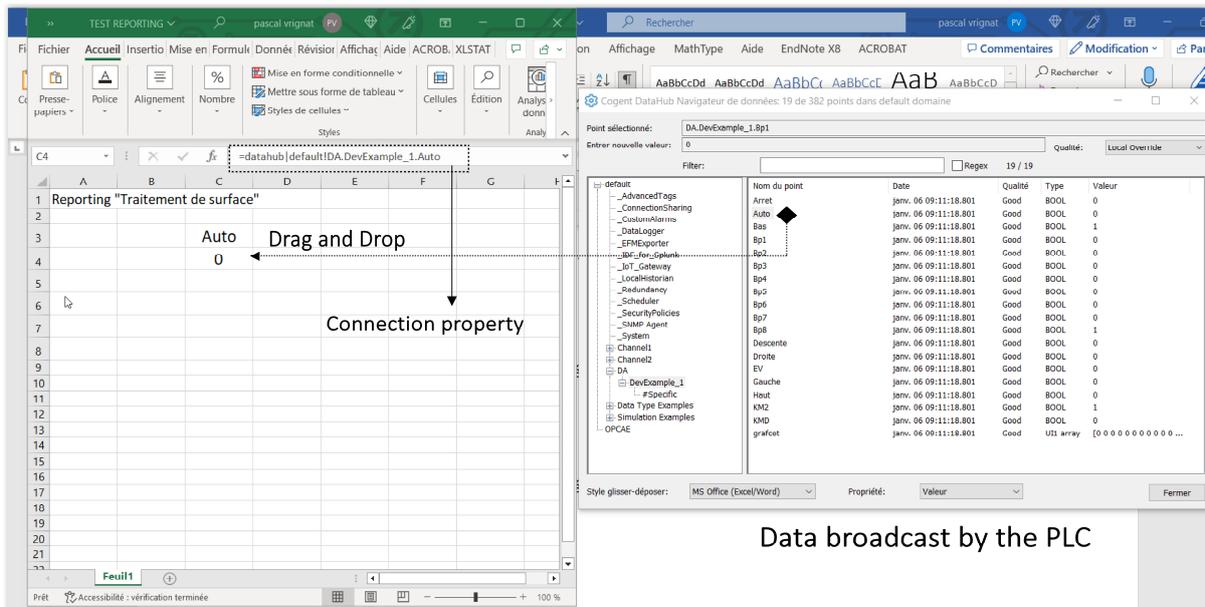


Figure 16 Configuration and provision of data by the PLC



Data broadcast by the PLC

Figure 17 Connection between Cogent DataHub and Excel

## 6. Some results with Excel and the Human-Machine Interface (HMI)

Figures 18, 19 and 20 present a development set that was proposed by a group of students (HMI part). In this context, they demonstrated and validated the initial requirements proposed in this work. These results meet the constraints outlined in Figure 7 satisfactorily.



Figure 18 Excel Home page

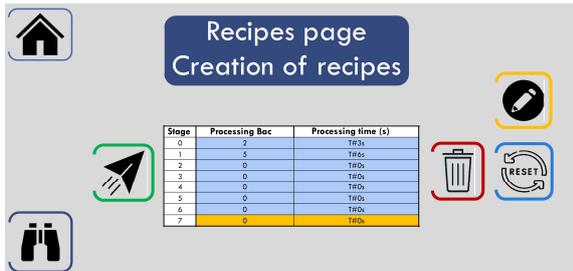


Figure 19 Excel recipes page

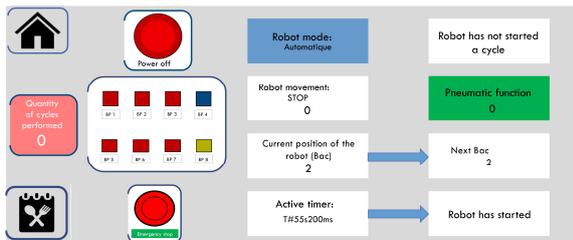


Figure 20 Excel reporting page

## 7. Conclusion

This work carried out with students demonstrates that our university's technological and scientific training is intended to respond to the needs and challenges associated with Industry 4.0. We have also shown that the transmission of knowledge and skills can be based on a so-called "PBL" pedagogy. In this topic, students have also made significant progress in terms of skills associated with industrial computing. Studying and implementing real-technical solutions also helps to motivate students. At the end of the project, each group presents its work, respecting the different technical delivery phases of a project.

## 8. References

- [1] Y.-H. Wang, "Integrating games, e-books and AR techniques to support project-based science learning," *Educational Technology & Society*, vol. 23, no. 3, pp. 53-67, 2020.
- [2] T. K. Chiu, C. S. Chai, P. J. Williams, and T.-J. Lin, "Teacher professional development on self-determination theory-based design thinking in STEM education," *Educational technology & society*, vol. 24, no. 4, pp. 153-165, 2021.
- [3] P. Vignat, M. Avila, P. Marangé, and F. Kratz, "University Education Adapts to Industry 4.0 Topic," in *International Conference on Remote Engineering and Virtual Instrumentation*, 2023, pp. 689-701: Springer.
- [4] R. Ramanathan, "The IEC 61131-3 programming languages features for industrial control systems," in *2014 world automation congress (wac)*, 2014, pp. 598-603: IEEE.
- [5] M. H. Schwarz and J. Börcsök, "A survey on OPC and OPC-UA: About the standard, developments and investigations," in *2013 XXIV International Conference on Information, Communication and Automation Technologies (ICAT)*, 2013, pp. 1-6: IEEE.
- [6] G. Ferreira Peña, "Back-end development of a Profinet-based data collector application and final deployment," 2018.
- [7] P. Vignat, B. Roblès, M. Avila, and F. Kratz, "OPC UA: examples of digital reporting applications for current industrial processes," *DEStech Transactions on Engineering and Technology Research*, no. ecar, 2018.