

## Design and control of a car park

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### -----ABSTRACT-----

*This work shows an application in the area of programmable logic controllers (PLCs). By means of a simulation in TIA Portal, a program that reports the occupancy of a parking lot was implemented, with a maximum capacity of 12 parking spaces. To achieve this, a parking lot with 2 sensors installed was required, and with the objective of counting the number of cars entering and leaving, one sensor was installed at the entrance and another one at the exit. To inform the user about the parking lot status, two messages were required: "Parking full" and "Parking available". And as a complement, a display was needed to inform about the number of available spaces. And finally, it is important to mention that a Human Machine Interface (HMI) was required to carry out the above.*

**KEYWORDS:** Programmable logic controllers, Human Machine Interface (HMI), Parking

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## I. INTRODUCTION

A programmable logic controller, better known by its acronym PLC (Programmable Logic Controller), is a computer, used in automatic engineering or industrial automation, to automate electromechanical processes, such as the control of factory machinery in lines of assembly or rides. However, the most precise definition of these devices is that given by the NEMA (National Electrical Manufacturers Association) which says that a PLC is: "Electronic instrument, which uses programmable memory to store instructions on the implementation of certain functions, such as logic operations, sequences of actions, time specifications, counters and calculations for the control by means of analog or digital I/O modules on different types of machines and of processes" [1].

The field of application of PLC is very diverse and includes various types of industries (e.g. automotive, aerospace, construction, etc.), as well as machinery. Unlike general purpose computers, the PLC is designed for multiple input and output signals, wide temperature ranges, immunity to electrical noise, and resistance to vibration and shock. The programs for the control of the operation of the machine are usually stored in backup batteries or in non-volatile memories. A PLC is an example of a hard-real-time system where output results must be produced in response to input conditions within a limited time, which will not otherwise produce the desired result [2].

Among the main advantages that these electronic devices have are that, thanks to them, it is possible to perform operations in real time, due to their reduced reaction time. In addition, they are devices that easily adapt to new tasks due to their flexibility when programming them, thus reducing additional costs when preparing projects. They also allow immediate communication with other types of controllers and computers and even allow network operations. As previously mentioned, they have a stable construction as they are designed to withstand adverse conditions such as vibrations, temperature, humidity, and noise. They are easily programmable through quite understandable programming languages. However, they have certain disadvantages such as the need for qualified technicians to take care of their proper operation [3].

Also, PLCs are widely used in the industry because they help not only to improve performance, but also to reduce labor costs, due to the automation of processes. They also contribute to process monitoring because when an error is detected, it can be stopped or corrected immediately. PLCs also allow savings in operating, maintenance, and energy costs. And one of its main advantages is that they can be programmed in different languages, highlighting the ladder programming due to its simplicity [2].

This article first discusses the basics about PLCs, then the methodology required for the design and programming of a simulation that reports the occupancy of a parking lot is presented, the main results are also reported, and finally the conclusions and references are highlighted.

## II. METHODOLOGY

### Equipment required

The controller used was the SIMATIC S7-1200 with CPU 1214C AC/DC/Rly V4.2 which has the following description: Work memory 100 KB; 120/240VAC power supply with DI14 x 24VDC SINK/SOURCE, DQ10 x relay and AI2 on board; 6 high-speed counters and 4 pulse outputs on board; signal board expands on-board I/O; up to 3 communication modules for serial communication; up to 8 signal modules for I/O expansion; PROFINET interface for programming, HMI and PLC to PLC communication.

The Human-Machine Interface (HMI) used was the KP700 Comfort SIPLUS with a 7" Display with the following description:SIPLUS article number: 6AG1 124-1GC01-4AX0;7.0" TFT display, 800 x480 pixel, 16M colors; Key operation, 24 function keys, 28system keys; 1 x MPI/PROFIBUS DP, 1 xPROFINET/Industrial Ethernet interface with MRP andRT/IRT support (2 Ports); 2 x Multimedia card slot; 3 x USB;Additional SIPLUS properties: protective coating against corrosive environmental conditions.

### Graphical interface design

The first step consisted of designing the graphical interface. Figure1 shows the parking spaces that were created using basic drawing tools.

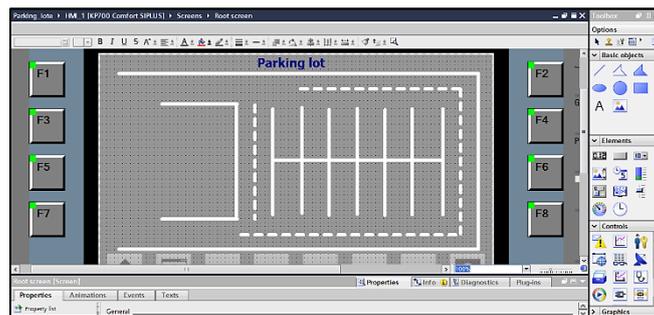


Figure-1 Design of parking spaces.

It was necessary to add 2 buttons to simulate the entrance and exit sensors respectively. The sensors can be seen in Figure2. It was also necessary to assign two action events to each button, this means that the first event consisted of setting the bit of the Entrance/Exit variable to logic "1" each time the button was pressed and the second event consisted of resetting the bit of the Entrance/Exit variable to logic "0" once the button was released (Figure3 and Figure4).

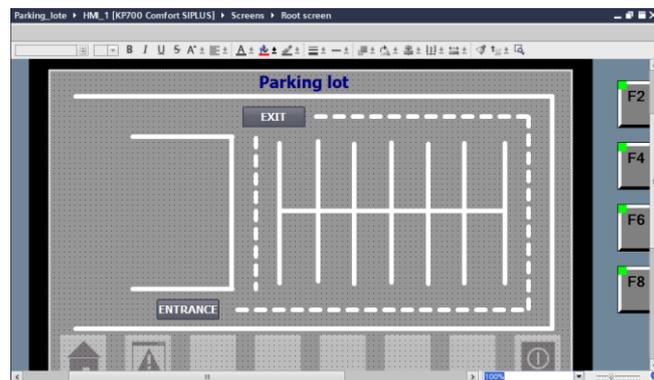


Figure2- Addition of Entrance/Exit sensors (buttons).

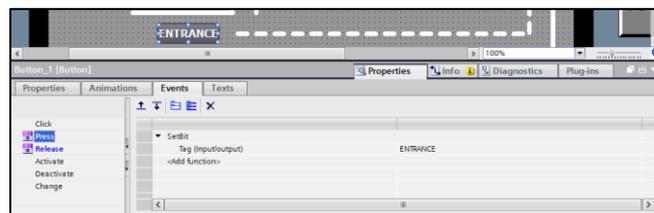


Figure. 3- Action event "Press".

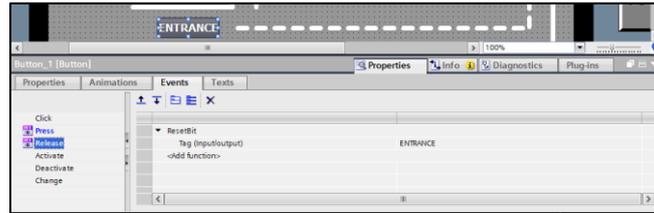


Figure4 - Action event "Release".

It was necessary to add 2 displays, one of them was associated with the variable "Counter", which would inform about the number of cars that have entered the parking lot, while the other screen was associated with the variable "Parking spaces available" which would inform about the availability of the parking lot (Figure 5).

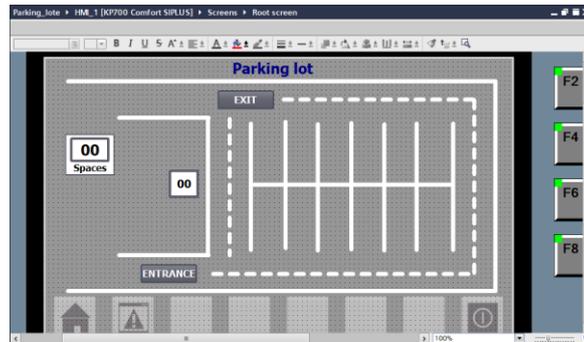


Figure5-Displays that would inform about available parking spaces.

The messages "Parking full" and "Parking available" were created to inform about the availability status of the parking lot (Figure 6).

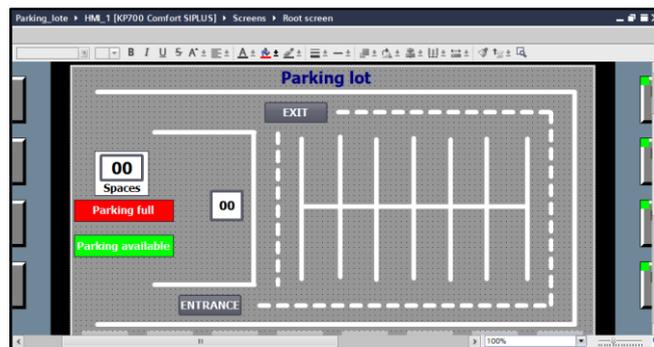


Figure6- Availability status of the parking lot.

The operating mechanism of the "Parking full" message is illustrated in Figure 7. In a simplified way, this message would only be displayed when the bit of the "Full" variable is set to logic "1".

Similarly, the operating mechanism for the "Parking available" message is shown in Figure 8. In general, this message would remain visible only until the "Full" variable bit changes to logic "1".

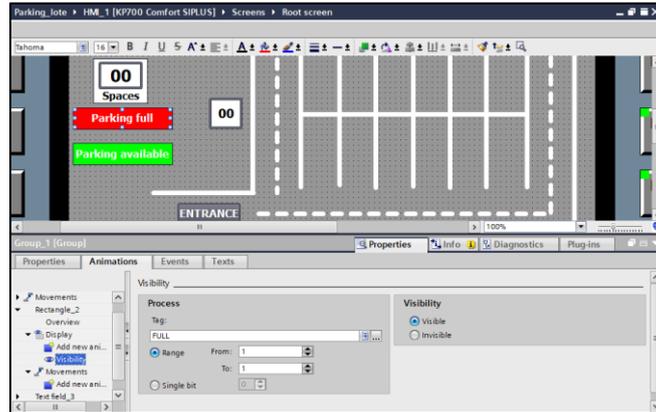


Figure 7- Animation of the "Parking full" message.

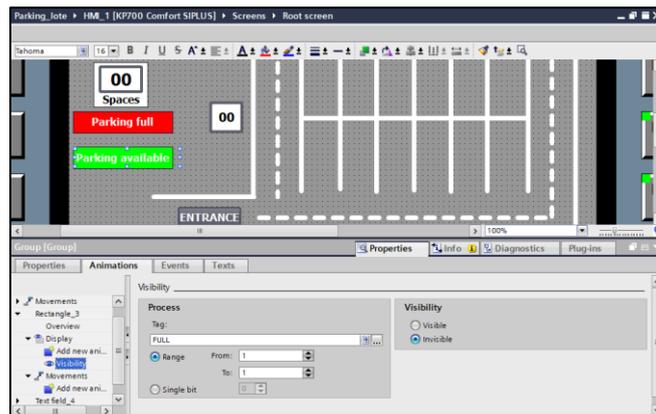


Figure 8 - Animation of the "Parking available" message.

To conclude this section, Figure9 shows the design of the cars. To do this it was necessary to use basic drawing tools.

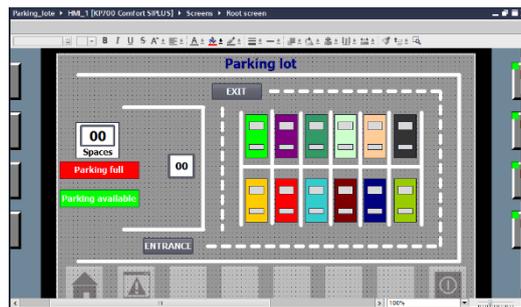


Figure 9 - Final part: design of the cars.



Figure 10- Principle of operation of the car animation.

Basically, the simulation of this parking lot consists of the gradual appearance of each car once it has been detected by the entry sensor. This means that each time the "Entrance" button is pressed, by means of a

simulation, a car would be positioned in its respective place, understanding that a car would stop occupying its place the moment the "Exit" button is pressed. This operating mechanism is illustrated in Figure 10, whereby means of an animation and considering the current value of the "Counter" variable, each car would be visible within a range. In this case the car would only be visible when the value of the "Counter" variable is within the range 3 to 12.

### Ladder programming

To start with the ladder programming, the first 2 sections are shown in Figure 11. Segment 1 shows the normally open contactor associated with the "Entrance" button which, once activated, sets the coil and the normally open contactor (both associated with the "Parking Pen Ent" variable) to the logic value "1". Once this is done the timer "%DB1" (of segment 2) is activated, which triggers a delay of 2 seconds, then the coil "%Q0.0" is reset. These 2 segments simulate the operation of the parking pen, which rises for a few seconds, then allows access to the car and finally returns to its initial state.

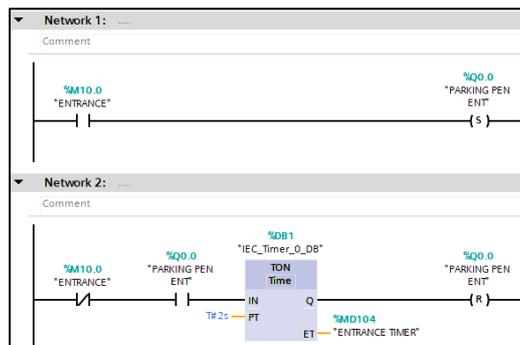


Figure 11- Segment 1 and segment 2 of ladder programming.

Similarly to the previous cases (Figure 12), segment 3 shows the normally open contactor associated with the "Exit" button which, once activated, sets the coil and the normally open contactor (both associated with the "Parking Pen Exit" variable) to the logic value "1". Once this is done the timer "%DB2" (of segment 4) is activated, which triggers a delay of 2 seconds, then the coil "%Q0.1" is reset. These segments 3 and 4 similarly simulate the operation of the parking boom, which rises for a few seconds, then allows the car to exit and finally returns to its initial state.

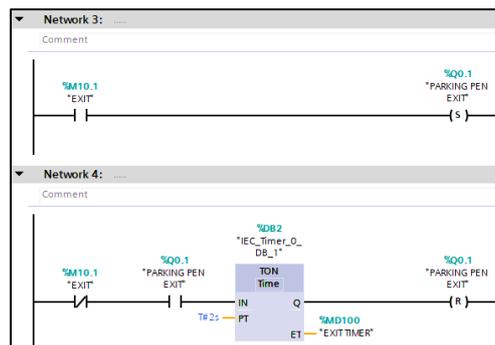


Figure 12- Segment 3 and segment 4 of ladder programming.

Segment 5 represents the most important part of ladder programming (Figure 13 ). Here it was necessary to use a counter of the type: "Counter Up and Down", this means that the value at the CV output is incremented and decremented.

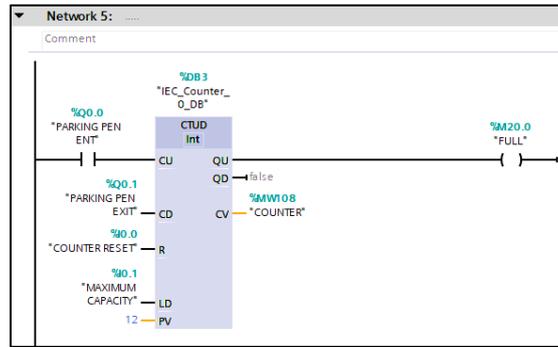


Figure 13 - Segment 5 of ladder programming.

The mechanism of operation is as follows: when the logic state changes from 0 to 1 in the variable "Parking Pen Ent" the counter increases by 1, and this count value is reflected in the variable "Counter", which displays the number of parked cars on a screen. On the contrary, when the logic state changes from 0 to 1 in the "Parking Pen Exit" variable, the counter is decremented by 1. The maximum count value is set to 12 in the PV input, which represents the maximum possible number of parking spaces. And once the "Counter" variable reaches 12 the coil associated to the "Full" variable is set to logic "1", this is when the message "Parking full" is displayed. It is important to mention that as long as the coil is not activated, the message "Parking available" will be displayed.

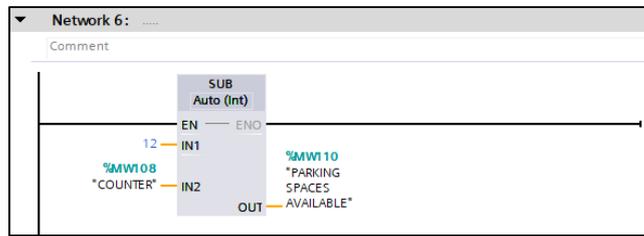


Figure 14 - Segment 6 of ladder programming.

To finish with segment 6, it was necessary to use the "SUB" programming block. As shown in Figure 14, this block subtracts the current value of the variable "Counter" from the maximum value of parking spaces (12), reflecting the result of this arithmetic operation in the variable "Parking Spaces Available", to display the number of available parking spaces on a screen.

### III. RESULTS

This section presents the evidence from the parking management simulation. To do this, it was necessary to have the TIA (Totally Integrated Automation) Portal V16 and its simulation add-on "SIMATIC WinCC Runtime Advance" in order to implement the HMI.

The simulation begins with the presentation of the HMI, Figure 15 shows the parking lot where the following is highlighted: first of all, the parking lot is completely empty, which is why the "Parking available" message is displayed. And another screen informs about the 12 available parking spaces.

Figure 16 shows that at the moment the "Entrance" button is pressed (simulation of an entrance sensor), a car is positioned inside the parking lot. And the displays report that there are 11 parking spaces available, so the display of the variable "Counter" shows "1".

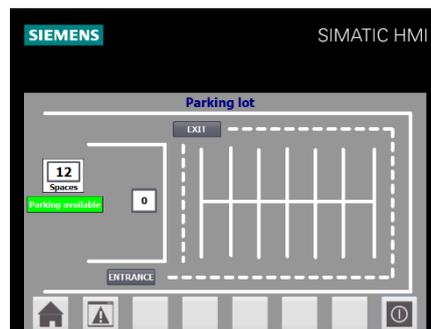


Figure 15 - Empty parking lot.

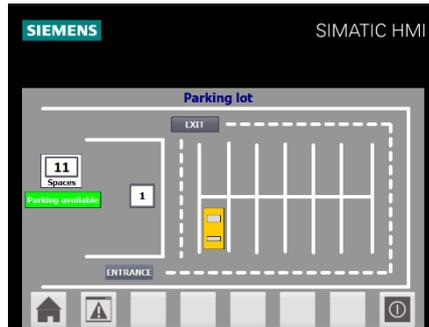


Figure 16 - Parking with 11 parking spaces available.

The animation of the order of positioning of the cars in the parking lot was arbitrarily defined. Fig. 18 shows the case where 7 cars have found a parking place, so there would still be 5 parking spaces available.

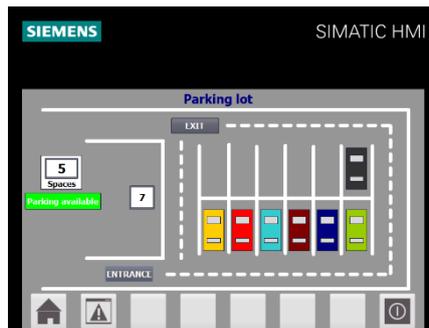


Figure 17 - Parking with 5 parking spaces available.

Figure 18 illustrates the case where the parking lot is at maximum capacity. As can be seen, the message "Parking full" has been displayed and the screens inform that all 12 possible parking spaces have been occupied.

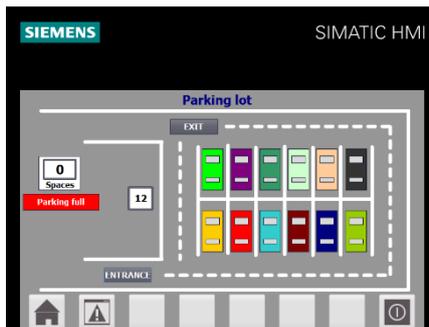


Figure 18 -Parking full.

And finally, Figure 19 shows the case where a car leaves the parking lot after having been at maximum capacity. As shown, the message "Parking available" is displayed and the screens inform that a parking space is available.

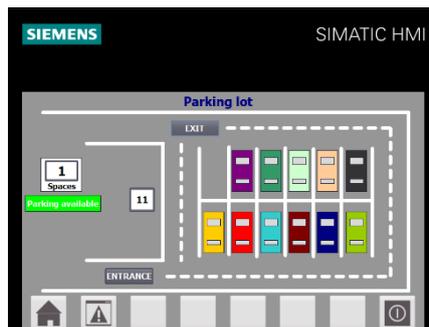


Figure 19 - Parking with only 1 parking space available.

#### **IV. CONCLUSION**

The development of a simulation that informs about the occupancy of a parking lot through the use of a programmable logic controller (PLC), allowed the development of important competencies in the professional training of an engineering student. This means that it was necessary the knowledge and development of skills in ladder programming, logical thinking, problem solving, creativity and management of new technologies. Furthermore, this application example is evidence of the wide problem-solving capabilities of these programmable logic controllers (PLCs), whose main field of use is industry.

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