Development of machine steering with use of PLC as introduction to 4.0 Industry

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Abstract. Article was written in order to make an attempt at developing a simple steering system for numerically controlled machines, with use of virtual modelling environment and an actual driver together with HMI panel. It was made as a response to demand of centralized system for steering a smart factory containing many machines. In the article, creation of a simple single machine steering system was described, which can be upscaled to the entire production hall. Used steering in this case is setting of position in an absolute system, in which only 3 variables X, Y and Z are known, and the operator can perform a correction of location and speed. Obviously, in real conditions these values will be set by a different program - like a post processor generating G-code. Usage of one data communication server can allow integration of devices within one production, and this allow creation of a smart factory suitable for 4.0 industry. In order to obtain such communication, an OPC server was used. Furthermore, the process of creating and connecting machines or programs to it was briefly presented.

1. Introduction

1.1. Hardware in the loop
Undoubtedly one of most important issues regarding modern factories is the optimization of machine movement system and production. Nowadays factories are built in the shortest possible time in order to minimize losses and to make profits as fast as possible. For this purpose, simulation of an entire production process of a given line in order to optimize it is helpful. This simulation can be done without using real steering devices. In this case, the software-in-the-loop simulation is used, although in the later step, it is recommended to perform a hardware-in-the-loop simulation. Work scheme of such loop based can be presented using schematic way [1-4], what is presented in figure 1:

![Figure 1. Scheme of Hardware in the loop.](image-url)
Entire process can be described this way: controller (right figure) receives information about current state of simulated object (left figure), and then does a correction using positioning movements. Extremely important advantage of this way of simulation is the possibility of the most precise mapping of a real signal flow in real-time without risk of damaging the executive elements [4-6].

1.2. Industry 4.0

In a nutshell, Industry 4.0 is the next revolution of industrial process, which was firstly mentioned back in 2011, and thanks to which it is assumed that factories can run 30% faster with 25% efficiency growth [7, 8].

More specifically, it will consist of integrating many devices currently working in an automated way, but without mutual communication between themselves. Undoubtedly in order to allow such communication, some data management center should be started, like an OPC server, which will be used in development of the current article [7, 9, 10].

Mutual communication between devices will also allow to better manage the factory as a whole, and increase the automatization, but also customization of the production. Great example of the last one can be a factory in which the model in a computer will generate a G-code, then communicating, for example, through an OPC server with a robot, fix the machined object on a machine, and then the machine also being an integral part of the base in factory would machine the detail basing on the provided code. Even though this vision still is a long way off, there already are companies that in an automated way implemented production that is to certain extent customizable. Example of such company can be Misumi, which using this solution is able to deliver its products to clients all around the world in a few days, allowing the clients to choose from 80 sextillions ($10^{21}$) configurations. Example view from a factory of this manufacturer can be seen in figure 2 [11, 12].

Figure 2. Misumi factory [11].
2. Preparation of the machine tool - declaration of objects types

Entirety of work will be done in the following software: NX by Siemens and Automation Studio by B&R. First one will be responsible for the simulated milling machine, and the second one for the controller. The machine will be controlled using 3 coordinates using the absolute method, that is, the specific coordinates of a specific machine axis will be given. The milling machine that will be used as an example of a controlled machine is a simple machine made of aluminum. Whole steering can be described using scheme in figure 3.

Information shared as required position and speed are transferred via an Ethernet cable from a PLC/industrial PC to a PC, specifically to the model in NX program. The other way transferred are the information about current position and speed of an object on a specific axis, what allows to control the executed move and monitoring the derogations. When it comes to model preparation, individual elements were declared as rigid body, what can be seen in figure 4.
Figure 4. Declared bodies in machine.

Milling machine frame was declared as a fixed joint, while the moving elements such as the table was declared as sliding joint, as seen in figure 5.

Figure 5. Joints of milling machine.
3. Obtaining communication between model and PLC
In order to allow information transfer between PLC and the model, an auxiliary system had to be chosen. Due to many advantages such as scalability and independence from Windows, an OPC UA server was chosen. It allows to communicate with many different objects using different system architecture. In order to activate the OPC server option, it must be enabled in the controller - example using the B&R controller can be seen in figure 6. It is also important to pay attention to the port number, as setting it will be required in order to correctly connect the synchronized simulation. Furthermore, communication on the first security level, that is without authentication should be enabled. Using this security level means that all certificates will be recognized as valid [14-16].

![Figure 6. Activating the OPC UA server in the controller.](image)

In the entire process a real controller is used, as seen in figure 7,

![Figure 7. Connected PLC.](image)

In order to connect both modules, an OPC server with a previously set port and selected security should be added, as in figure 8. In the given example the port is 4840.

![Figure 8. Adding an OPC UA server.](image)

Then, the signals from the chosen OPC server should be mapped with those appearing in the model. Individual connections were shown in figure 9. As seen, controlled will be both the speed and the position on specific axes.
4. Results

Control happens using the HMI panel visible in figure 10. As seen, various speed and exact position on a specific axis of a machine can be set in it.

![HMI Panel](image)

**Figure 10.** HMI Panel.

It can divided into 5 areas (like in figure 10):

1. Position given by the operator
2. Speed given by the operator
3. Real positions
4. Real speed
5. Picture with marked axes of the machine
Juxtaposition of the panel and obtained shift is shown in figures 11 and 12. Values are displayed in mm (position) or mm/s (velocity).

![Figure 11. HMI panel and simulation of machine work – current data from robots moves.](image1)

![Figure 12. HMID and simulation of machine work – the end of movement.](image2)

The comparison of figures 11 and 12 shows that the milling machine was moving in a way that was planned. As can be seen, the speed values displayed on the gauges are equal to the set ones (except the end position where they indicate 0). Moreover, the end position is equal to the specified one.

5. Conclusions
As part of the work, the connection was made between the simulated model and the controller, using the PLC. This connection was made successfully, and the machine is controlled to full extent in a global coordinate system. Basing on the obtained connection, person performing the simulation is able to read the given and the current location of an element and give their own in the operator panel.

Scope for development of current work is seen in the integration of a bigger number of devices in order to make a virtual factory, and in extending the possibilities of controlling a machine. As it was mentioned, it would be ideal to read the feed setting values using the program that will read them from the G-code, previously generated by the post-processor.
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