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# PROGRAMMABLE LOGIC CONTROLLERS IN PROCESS AUTOMATION

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**Abstract:** *Nowadays, control problems are solved using operating components from a wide variety of technologies: electronics, hydraulics, pneumatics and mechanics. Functionality, reliability and price of the controlled system are determined by the quality of the solution made.*
*The paper concentrates on practical use of programmable logic controllers (PLC) that is based on the five years project development experience in this area. Successful solutions and problems are under focus.*
*Specific hardware, controller programming problems, data/signals exchange and human machine interfaces are considered. As a result the method for selecting programmable controllers according to specific needs is developed. Practical suggestions, possible hazards and warnings are proposed that could help to avoid mistakes.*

Key words: *programmable controllers, PLC, automation, automation systems, process automation.*

## 1. INTRODUCTION

Modern machinery consists of both mechanical and electronic parts. Overall functionality is determined by "*balance*" between these components. Initial planning and solution selection plays critical role in final result.
In control methods the selection has to be made between relay-based circuits, special devices, programmable logic controllers (PLC) and new development electronics. This article is concentrated on PLC-s and experience that has collected over 5-year practical work with PLC-s. Strong and weak sides, positive and negative practices are discussed. Suggestions weather to use programmable controllers or not have been formed to help decision making.

The most important decision in planning PLC-based system is selecting processor type. Mistakes mean extra costs for modifications or even need for completely new devices. The most common error is overestimating programming possibilities of small-sized processors. There are several methods for selecting PLC. Unfortunately most of them focus on electrical side of PLC-s and maximum count of signals allowed. They don't involve analysis to determine possible special needs for user program or communications.

Based on several existing methods, practical experience and future trends a new method for selecting PLC was developed.
Ahti Mikkor has gained his experience by taking part in more than 15 big-scale automation projects. These projects include development of power consumption monitoring system in AS Kunda Nordic Cement factory, renewing testing rig for flowmeters, building Ahtme powerplant turbine safety systems, water treatment plants in towns Rakvere and Põlva, waste water treatment plant in town Jõgeva and development of monitoring system for central heating network in Tartu.

## 2. PROS AND CONS IN USING PROGRAMMABLE LOGIC CONTROLLERS

### 2.1 Positive arguments

The main advantage that programmable controllers provide is flexibility (Jack, 2003). Behaviour of the system can be easily changed via program without any other alterations. Special devices for example make any changes in control algorithm very hard to implement. Flexibility makes PLC-s well suitable for frequently changed applications, for example in robotics.
In PLC-s the relations between inputs and outputs are determined by user program. By using advanced programming technologies it is much easier to implement complex control algorithms than in any hard-wired solutions. It makes PLC-s very competitive for complex tasks, for example in controlling chemical processes.
Special modules allow vast amount of different signals to be connected to the PLC system. Use of PLC-s should be considered in applications that require some "*special*" input or output signals. Typical example would be positioning using reference data from high-speed input.
Typically PC visualization software packages are made for PLC-s. Some special devices have also PC software packages. Wide range of communication options between PLC-s makes it possible to gather all information from field devices into one central control point.
Communication lines between PLC-s allow using information collected from other parts of the system in local process control. Modern communication technologies enable remote diagnostics and configuration (Jack, 2003). These two significantly reduce overall maintenance costs of the system.

### 2.2 Negative arguments

Programmable controllers are not equipped with enough memory to store big amounts of data. Although future trends show growth in PLC memory sizes, special devices (recorders) are still better suited for standalone datalogging applications. For networked solutions there is possibility to use visualization software packages together with PLC-s to archive collected data in any database format necessary. If logged data amounts are small or there are also control functions included, it's reasonable to still use PLC-s. About visualization software packages it's good to know that in standard versions most of them do not support offline recording so that after communication breakdown it is not possible to acquire data backwards from PLC.
Modern communication options for PLC-s include standard protocols for example Ethernet. It is tempting to use existing office networks also as data carrier for automation system communications. Time has shown that it is better practice to keep these two separated if there is a need for constant online communication. Hardly traceable temporal network overloads can cause problems also in automation system communications.

All PLC-s need be programmed. All programming works include risk for accidental errors in control algorithm. Special devices are well tested and generally free of this kind of problems. If available, it's economically thoughtful to use special devices.
Safety applications that require highest degree of reliability should contain simplest devices and circuits possible. There is a rule that every new link in chain decreases overall reliability.
In small applications it's often cost saving to use relay-based circuits instead of PLC-s.

## 3. FUTURE TRENDS

Progress in process automation systems is aiming at so called *complete automation* when all the human has to do is to enter the parameters of the product wanted and everything else is carried out by machines (Rosin, 2000). Although the destination lies far ahead, trends indicate movement in that direction.
Firstly, systems become more and more standardized. Big manufacturers organize their products into families. The aim is to reduce amount of knowledge needed for configuration and maintenance works of different devices from same company. It's also important that this way built applications are easily expandable.
Secondly, importance of communication is rising (Hughes, 2000). There are many reasons, some of more essentials are:

- Better collaboration of different parts of the system.
- Cutting costs on cabling. Less cabling results fall in fault probability, but also increases severity of ones that occur.
- Sensors and actuators can be at longer distances from the processor module than if using conventional methods.
- Increased scalability of the systems. New devices can be added at minimal costs.
- At some cases it is better to make architecture of many small independent modules and network them. This solution enables system to keep working although some parts have failed.
- Communication networks ease fault diagnostics and provide remote management possibilities. Central operating stations can be formed relatively easy.
- Possibility to connect devices form different manufacturers (OPC Foundation, 2003).

Third important tendency is spreading use of so called *software controllers* or *Soft PLC*-s (Siemens AG, 2003). These are PC software-based solutions that relate with field devices via communication networks. There is no need for processor module, resources of PC are used. Some *Soft PLC*-s are still formed as processor cards for PC (figure 1). Reliable communication networks are essential. *Soft PLC*-s are well suited for data acquisition applications because of data storage possibilities of PC-s.

Figure 1. Siemens Simatic WinAC Slot PLC 412

Fourthly, combo-devices (figure 2) that contain both operator panel and medium size processor module gain popularity (Siemens AG, 2002). In this solution possibility of disturbances is low and reuse of some components make whole package cheaper.

Figure 2. Combo device Siemens Simatic C7-613

Fifthly, processor software takes over properties from PC software. Data collected from production can be easily transferred into office applications (Siemens AG, 2000).

## 4. METHOD FOR SELECTING PROGRAMMABLE CONTROLLER

A method for forming an application specific list of required properties for selecting programmable controller was developed. There are nine criterions and the results are presented in Table 1. Selection is made by comparing results table with controller's technical data. Following is short description of every criteria involved.
*Nature of solution* determines weather it is expanding of old system or completely new development. In first case the architecture of system and hardware requirements are limited by already existing solution. Using hardware from same company makes servicing easier and avoids integration problems that would occur when using products form different manufacturers. For example many hardware producers integrate their own specific communication interfaces directly into processor module and for every universal protocol a special module is needed (Siemens AG, 2003). It is also possible to reduce spare part stock amounts when using same type hardware all over the system.
*Maximum number of electrical inputs-outputs allowed* is classical criteria to determine processor class. If complex control algorithms and non-standard functions are needed, it's not the most important parameter any more. Generally it is money saving to use one bigger processor module for input-output signals that originate from nearby locations than several smaller ones. In this case there will be no need for communication network and programming will be easier too.
*Special signals and modules* are usually available for medium and large controller families only. Many microcontrollers do not even have possibility to add analogue output (Siemens AG, 2003). In some cases using special modules is the only way, in other ones (positioning) it is just an opportunity to save money.
*Layouts of sensors and actuators* can be very different, sometimes the sensors are located several kilometres away from the actuator (pumping liquids in long pipes). In this case special communication network (Profibus, AS-inteface) might be the only solution. If not, it can at least save costs by reducing cabling works. Not all programmable controllers have interfaces for communication protocols.
*Properties of processor* have important role in complex applications. Most common problem is lack of programming memory, sometimes also data memory. Memory requirements

can be estimated by number of input and output signals. But in practice 100 digital input-output points system often has 3 times smaller program than 10 digital input-output points system. The only way to estimate program size exactly is using previous experience.

*Program specialities* include special program functions needed. Different areas of applications have some typically used functions, for example temperature control in building automation. Programming is much simpler if these functions are already built into system software of processor. In process automation 2 digital output (up-down) closed loop PID regulation is quite often used. It might be a surprise but it's not included in most of the microcontrollers (Siemens AG, 2003) and for average programmer it's too complicated task to create his own regulator using standard functions. Basically there are 2 solutions: either to avoid this construction or to use applicable controller.

| Criteria | Selections | Comments |
|---|---|---|
| 1. Nature of solution | ☐ New system<br>☐ Existing system | Compability between new and existing devices |
| 2. Digital signals | Inputs _____<br>Outputs *relay* _____<br>*transistor* _____ | Number of signals |
| 3. Analogue signals | Inputs *current* _____<br>*voltage* _____<br>*temperature* _____<br>Outputs *current* _____<br>*voltage* _____ | Number of signals |
| 4. Special signals and modules | High-speed signals _____<br>☐ Positioning<br>Others: _____ | Special modules are not available for every PLC |
| 5. Layout of sensors and actuators | ☐ Local<br>☐ Periphery | Periphery might mean communication network |
| 6. Properties of processor | Program memory _____ kB<br>Data memory _____ kB | Rule: 10 bytes for digital and 25 for analogue input |
| 7. Program specialities | PID _____<br>Integrating PID _____<br>☐ Floating point math<br>Others: _____ | Integrating PID available only on some models<br>Many microcontrollers don't support floating point math |
| 8. Communication | ☐ Networked PLC-s<br>☐ Visualisation on PC<br>☐ ASCII (*freeport*)<br>Others: _____ | Every PLC has it's specifical possibilities for communication |
| 9. Working conditions | ☐ Temperature below 0 $^{0}$C<br>☐ Humidity | Special models for extreme conditions |

Table 1. Table for method results

*Communication* is becoming more important in nowadays automation systems. In some cases non-standardised devices as barcode readers or electronic weights have to be included into the system. Then it's vital to have functions for protocol programming (freeport programming). Standardised protocols demand existence of specific modules.

*Working conditions* can usually be overcome by using special cabinets, but there are also specific series of programmable controllers that have improved resistance for electromagnetic disturbances, humidity and vibrations. In very dusty environments all cooling ventilators have to be equipped with filters.

## 5. CONCLUSIONS

Main benefits of programmable controllers are:

- flexibility
- communication possibilities
- realisation of complex control algorithms
- reliability

Alternative solutions should be considered if:

- system is very simple
- special devices are available
- data recording is necessary

Initial selection of appropriate solution and hardware has great influence on final result. Mistakes in this step significantly increase overall budget of project as some programs might have to be changed and some hardware replaced.

Based on his practical experience the author has formed a method for selecting programmable controller. It has 9 criteria's:

- nature of solution (new or existing)
- maximum number of electrical inputs-outputs allowed (digital, analogue, inputs, outputs)
- need for special modules (high-speed digital outputs)
- layout of sensors and actuators (local or periphery)
- properties of processor (program and data memory)
- program specialities (special functions)
- communication needs (Profibus, ASCII)
- working conditions (humidity, temperature, vibration, dust)

Method is not guaranteed to always point out the best selection, but using it certainly avoids mistakes.

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