

A Concept of a Production Flow Control System Protocol to exchange Data and block defective discrete Products*

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Abstract

Simple data registration is often insufficient on its own, making the implementation of systems that enhance traceability with error-prevention and blocking features a crucial addition. Scientific literature typically focuses on product or process traceability limited to data collection and analysis, primarily through reporting. In contrast, the core innovation of the proposed Production Flow Control (PFC) protocol lies in its ability to automatically block defective products at the source of the issue by analyzing database content in real time. The development process began with the design of the PLC data block structure, followed by the creation of procedures on both the PLC and PFC sides. In addition, a communication algorithm between the PFC system and the PC controlling the production station was designed. A corresponding database structure, including functions and triggers, was also developed to align with the PFC communication protocol. This paper advances the understanding of Product Flow Control (PFC) systems by examining the underlying principles and functional concepts involved in their implementation. The proposed methodology is specifically designed for discrete manufacturing processes that handle distinct mechanical products. In the author's view, both scientific literature and commercial solutions tend to focus primarily on traceability - limited to data collection and registration - supplemented by reporting tools for reactive quality management. However, this may not be sufficient. As a result, the integration of a poka-yoke mechanism, such as a PFC system, is often essential to ensure proactive error prevention and enhanced process reliability.

Keywords: traceability, flow control, blocking of defected products

Introduction

Steghofer et al (2021) mention traceability refers to the ability to identify and monitor identifiable products or processes within a supply chain at all stages of production, processing and distribution. This process is based on the systematic collection and recording in appropriate databases of data obtained from production systems. Argilovski et al () as well as Cheshmberah et al (202) mention traceability systems as IT solutions can be used both to monitor internal production paths within a plant and to track the flow of products between individual links of external suppliers. Thanks to traceability systems, it is possible to recreate the full history of the product, including places and dates of transport and conditions in which the goods were stored. A detailed collection of information allows for the quick location of defective product batches and their withdrawal from circulation, as well as effective warning of consumers.

Production Flow Control (PFC) systems, apart from collecting traceability data and sending them to the traceability database over TCP/IP network, are IT solutions, which check operation results and reacts to negative ones by communicating with automation devices to block defective identifiable products just near the location,

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where the defect occurred. PFC systems can be seen as an advanced form of origin tracking systems. They enable the recording of the history of a single product in the form of subsequent production steps, taking into account such data as: date and time of operation, various types of numerical values, identifiers (including component identifiers), results of technological operations, as well as the workstation identifier. The collected information fully characterizes a given stage of production, which allows for analysis as well as, if necessary, thanks to the use of dedicated communication protocols and database functions, for blocking of a defective product, therefore preventing its transfer to the next stage of the process. This mechanism consists in physically securing the product against its removal from the workstation by an unauthorized person in case of detection of non-compliance and/or alerting methods. These defects may include, among others, incompleteness of the product, incorrect execution of a technological operation, following wrong technology route, incorrect component to be installed as well as the occurrence of products with duplicate identifiers. Detection of defects is based on automatic analysis of the contents of the registered information in a database, including information from previous workstations, as well as on the basis of the system configuration, such as: the right sequence of workstations for a given product type, expected components or possible alternative workstations. PFC systems help prevent from potential customer complaints or significantly reduce their number. These solutions bring benefits in terms of production management, by reducing the costs associated with handling complaints, and above all by increasing customer confidence, which translates into increased revenue and the possibility of acquiring new contractors.

PFC systems are in fact an extension of traditional traceability systems. Data is mainly obtained from PLCs and industrial computers, which control production stations. In this respect, PFC systems act as traceability systems, enabling the identification and monitoring of discrete products and processes in real time. These products can consist of both identifiable components (e.g. electric or manual actuators) and non-identifiable components (e.g. springs, screws, rivets). For this reason, PFC systems are particularly suitable for companies operating in industrial sectors such as automotive, aviation, machinery, heavy industry, marine, as well as in the medical devices industry. An additional advantage of PFC systems is their high configurability, enabling adaptation to various production line configurations, including in terms of station sequences, required components or the use of alternative stations.

General Characteristics of the proposed Communication Protocol

To start explanation about the basics of the protocol, first the concept of a Machine (M) must be introduced. A Machine can be one production station controlled by a PLC or PC as well as several stations controlled by one PLC or PC. All PLCs and PCs (Fig 1) use a standard interface (communication protocol) to communicate with PFC system. The communication proceeds as a telegram system between a PLC and the PFC. The communication system is TCP/IP. Data is always prepared inside the PLC and collected by the PFC.

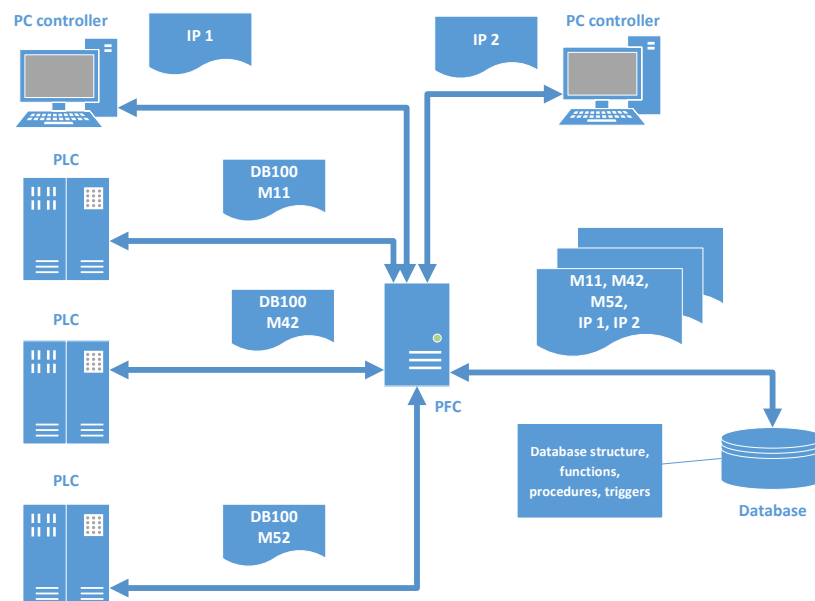


Fig 1. PFC system's interfaces [source: own development]

In case of communication with PC identified by IP address, the interface consist of a set of specialized text strings exchanged according to a defined sequence (see Fig. 4). In case of PLC, the interface consists of a standard data structure (data block – let’s name it DB100) and filling-in procedures. In case when one PLC controls several work stations, there shall be built a buffer inside the PLC consisting of several DB100 (DB100 matrix like) to store the operations’ results. After operation on a part is finished, the PLC of the Machine writes resulting data into the DB100 as well as the value “3” into the variable (PLC) “Request number” which means that data for PFC is ready. Then the PFC application reads the content of the DB100 data structure in the PLC and adds it to the other data for the part (part’s history) in the database. As the feedback the PFC fills-in the following variables in the DB100:

- (PFC) “PFC result” of 30 (success) or 31 (no success),
- (PFC) “Request number” set to 103.

If complete data is delivered by PLC, PLC sets (PLC) “Request number” variable to 0 (Fig 2).

If there is a need to ask PFC to allow to proceed, PLC puts (PLC) “Request number” value to 2 (cross-check request) and receives back (PFC) “Request number” value as 102 and, after PFC checks product’s history in the database, (PFC) “PFC result” as 20 (allow) or 21 (block).

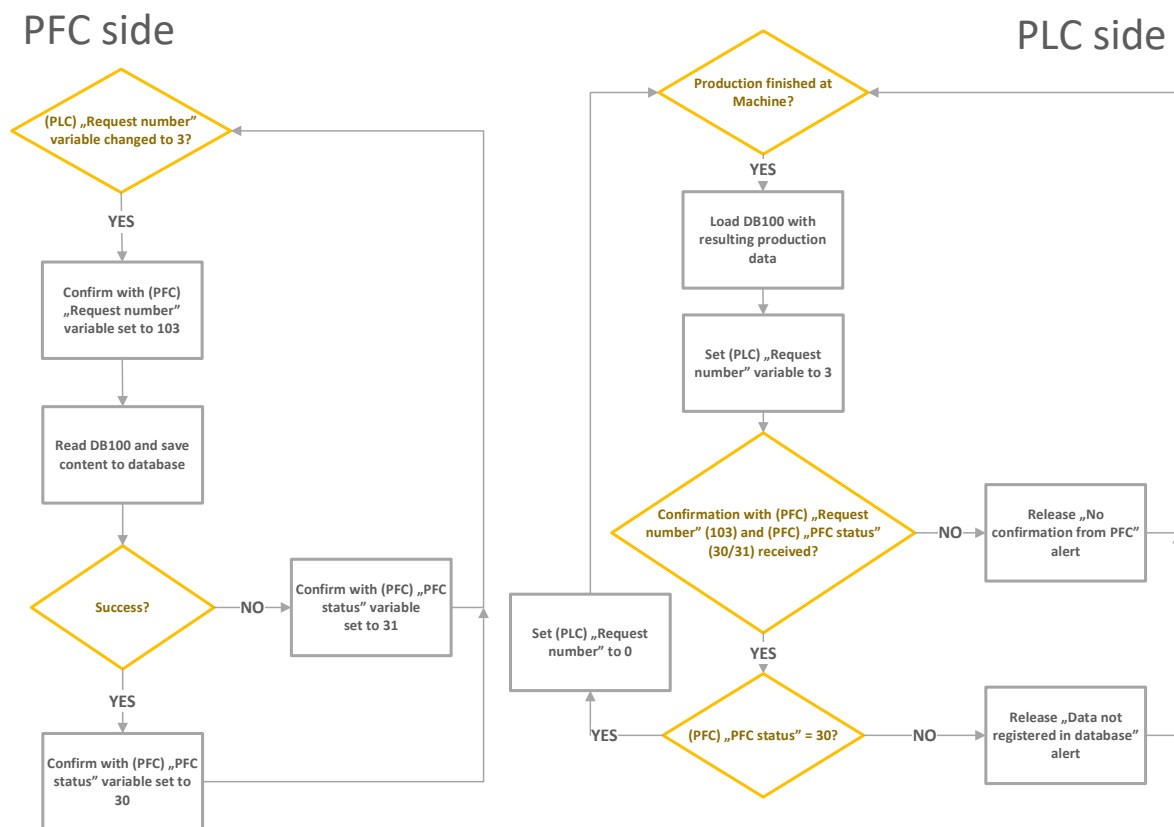


Fig 2. PFC and PLC communication algorithms [source: own development]

Data Structure (DB100)

Every Machine has its own DB100 area with all data for a complete flow control. For that, the PLC provides only the necessary DB100 and the communication port. The PFC establishes the communication with the defined IP address and port. The PFC reads data from the defined DB100 and also writes back into the same DB. Two different areas are set in the DB100 (Fig 3):

- the first area is the PLC area where the PLC writes actual product’s information, e.g. product code (identifier), screwdriver results, riveting results etc. This area is forbidden to be over-written by the PFC,

- the second area is PFC area. It is the area where the PFC returns an answer after receiving data from the PLC. This area is forbidden to be filled-in by the PLC.

In order to keep the ability to match extended requirements regarding PFC, the concept of “pfc value” is introduced. Both DB100 and the database have a “PFC Value” table with 3 fields: Name, Result, Value. Such structure allows to store results from automated actions on a Machine, e.g. riveting, screwing etc. A “PFC Value” is related to a Machine, and multiple “PFC Values” can be related to the same Machine. Neither Result nor Value is mandatory, one of them or both can be filled-in. The Name, which shall be of integer type, has no constraint on its content, but its value has to be agreed between PLC/PC and PFC developers. The name of the value as character string is defined then in the database.

Communication in case of PC controller

In case a PC controls a Machine, a special protocol is to be applied based on text strings exchanged according to a 2-phases procedure (Fig 4). Within first phase, after scanning product code by an operator at a Machine, the PC controller sends Q-telegram, which includes product identifier, to check, if it is allowed to continue. It shall receive Q-answer from PFC after it checks products’ process results and history in the database. The negative answer shall cause blocking of the product at the Machine. After production operation is finished at the Machine, the PC controller sends F-telegram, which contains process results and receives from F-answer back from PFC, which contains confirmation of receiving the message as well as the result of data storing in the database.

PFC	Live_counter	INT
	PFC_result	INT
	Request_number	INT
	Assembling_result	INT
	Line_number	INT
	Station_number	INT
	Version	CHAR[0..25]
	Reference	CHAR[0..10]
	Product_code	CHAR[0..30]
	Operator_id	INT
	PLC	Live_counter
PFC_result		INT
Order_number		INT
Assembling_result		INT
Line_number		INT
Station_number		INT
Version		CHAR[0..25]
Reference		CHAR[0..10]
Product_code		CHAR[0..30]
Operator_id		INT
Component1		CHAR[0..30]
Component2		CHAR[0..30]
...		
Component10		CHAR[0..30]
PFC_value_name1		INT
PFC_value_result1		INT
PFC_value_value1		REAL
...		
PFC_value_name30		INT
PFC_value_result30		INT
PFC_value_value30	REAL	

Fig 3. DB100 general structure

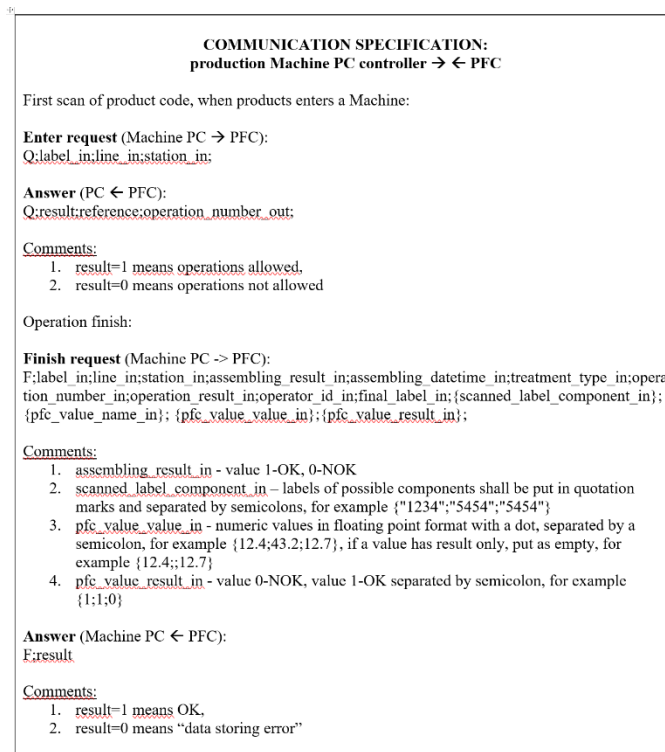


Fig 4. Communication protocol with PC, which controls a Machine, based on Chrobot (2025)

Final Findings

The idea presented in the paper is based on author's observations of discrete manufacturing processes of mechanical products as well as gathering and analysis of industrial requirements and expectations regarding a PFC system. Such a structure of a computer system is caused by the needs of the industry, its functional expectations, as well as the structure of a discrete production system. Author has not found any information about a PFC system concept published, especially with regard automatic blocking of a defective product near at location of a problem (i.e. in case of defects made on previous workstation, or in case of following wrong sequence of workstations) based on database querying, nor there is an IT solution commercially offered. This paper contributes to the body of knowledge on PFC systems by exploring the principles and functional concepts behind their implementation. According to the author, scientific publications and commercial offerings often emphasize traceability, mainly through data logging and registration, and are typically supported by reporting tools aimed at reactive quality control. However, this approach alone may fall short. Therefore, incorporating a poka-yoke mechanism, like a Process Failure Control (PFC) system, is frequently necessary to actively prevent errors and improve overall process reliability.

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