Development of Industrial Control System project for handling goods stored in a finished goods warehouse of bulk goods producers

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Abstract. Nowadays in the Russian Federation, automation of the main production unit along with additional mechanized side lines is very typical for non-food producers of bulk goods built in the USSR. This pattern is usually supported by outdated mechanical equipment in the side lines that requires manual control of processes. Therefore, the situation when the finished goods warehouse is the weak spot of the enterprise is very common. It may reduce the overall productive efficiency, increase manufacturing costs and decrease the main economic indicators of the entire enterprise. The article studies currently important development of a project of an automated control system for the process of handling goods in the finished goods warehouse (Industrial Control System for Handling Finished Goods), integrated into the centralized enterprise control system on the basis of a single information space. The paper is focused on the standard structure of a finished goods warehouse where the finished goods are reloaded into a temporary storage of bunker type. Standard scheme for installation of the operational units' sensors is also considered as well as some issues of operational unit manual control management and common technological constraints. Key project objectives are formulated. A typical stand-alone operator task is formulated for the Industrial Control System for Handling Finished Goods. At the end of the article, a model for organizing the Industrial Control System for Handling Finished Goods algorithm into conceptual units is proposed.

1. Introduction
The Russian factories built in the USSR often use modern automated control systems on their main production unit [1-3]. This allows them to automate all processes. However, side lines (feeding raw materials, finished goods warehouses, etc.) are often mechanized rather than automated, so all the operations can only be performed manually. In many cases, this is caused by outdated mechanical equipment in the side lines that requires manual control of the processes, because the equipment was designed without the idea of complex automation in mind [4, 5] Therefore, such manufacturing process requires a lot of well-trained operators and maintenance stuff because sometimes it can be quite difficult to detect the equipment failures [6, 7]

It is typical for non-food producers of bulk goods with a wide range of products (such as fertilizers, products, etc.) to lack the complex automation of the goods handling processes in the company's finished goods warehouse. Usually, the finished goods are transferred to the warehouse from production.
workshops via conveyors, after that, they are distributed between temporary storage bunkers discharging the product when it is sold to the final customers [8, 9].

When the main production unit is automated, the finished goods warehouse may become the weak spot of the enterprise. It may reduce the overall productive efficiency, increase manufacturing costs and decrease the main economic indicators of the entire company. Therefore, nowadays the development of the Industrial Control System for Handling Finished Goods (ICS HFG) in the finished goods warehouse for such enterprises is important and on-demand.

In modern conditions, it makes a lot of sense to develop a project of the Industrial Control System for Handling Finished Goods (ICS HFG) integrated into the centralized enterprise control system (automated ECS) on the basis of a single information space (SIS).

2. Production area standard structure. Installation of operational units' sensors. Operational units manual control management
A standard finished goods warehouse of a factory built in the USSR consists of three floors. There are two conveyors on the second floor used for transferring goods from the production workshops. At the end of every conveyor there is a vertical conveyor (vertical conveyor) delivering goods to the third floor, where the sorting system is placed, and transporting them to horizontal conveyors HC11 and HC21. The goods are transported to the loading area of storage bunkers B1-B24 via these conveyors. The unloading of goods from the storage bunkers is carried out on the first floor.

Technological constraints.
1. The goods can be simultaneously loaded into one of the storage bunkers B1-B24 only.
2. The goods must not be loaded to and discharged from the storage bunker at the same time.

The layout of storage bunkers and operational units with drives is shown in figure 1.

![Figure 1. Layout of storage bunkers and operational units with drives.](image)

1. B1-B24 – storage bunkers.
2. Operational units:
VC1, VC2 – vertical conveyors  
HC11, HC12, HC21, HC22 – horizontal conveyors  
S1 – S12 – flow switchers  
SG1 – SG24 – slide gates of storage bunkers  
3. Drives of operational units:  
VCD1, VCD2 – drives of vertical conveyors  
HCD11, HCD12, HCD21, HCD22 - drives of horizontal conveyors  
SD1 – SD12 – drives of flow switchers (not shown)  
SGD1 – SGD24 – drives of storage bunker slide gates (not shown)  
4. Sensors – not shown, standard installation scheme

**Installation of operational units’ sensors**  
Vertical conveyor:  
a) support for goods – MERA B314,  
b) speed check relay – IFM DI602A,  
c) conveyor belt (4 pcs.) – IFM ID5005  
Conveyor:  
a) support for goods – MERA B314 or IFM II5320,  
b) speed check relay – IFM DI602A.  
Slide gate:  
a) position sensor – limit switch or IFM II5320.  
Reversing valve:  
a) position sensor – limit switch or IFM II5320.  

**Operational units manual control management**  
For operational units (vertical conveyor, conveyor, slide gate, reversing valve) in addition to auto mode, a manual control mode with disabled automatic control functions shall be developed.

3. **Key project objectives. Operator task for ICS HFG. A model for organizing the Industrial Control System for Handling Finished Goods algorithm**  
Main goals of the project are the following:  
1. The improvement of finished goods warehouse and enterprise management efficiency by using SIS and automation of:  
   - information processes supporting goods handling,  
   - technological process of goods handling,  
   - record of finished goods movement,  
   - diagnostics and accounting of production equipment technical condition,  
   - gathering statistical data about finished goods warehouse production processes.  
2. More precise control of the technological process, lower impact of the human factor on production operations and decision-making processes.  
3. Programmed check of operations and diagnostics of current state of operational units, prevention of emergency.  
4. Information support for detection and further use of the ways to save manufacturing and non-manufacturing costs; creation of a basis for making high-quality management decisions.  

**Typical task:**  
TS = TS (TG, NG, BNWL) from an operator or central management system for Industrial Control System for Handling Finished Goods contains the following data:  
a) loaded goods type (TG),  
b) quantity of goods (NG),  
c) storage bunker No. where to load goods (BNWL).  

**General algorithm** for Industrial Control System for Handling Finished Goods can be divided into the following subtasks.  

**TS1**  
Current free space control for all bunkers (DB_BNK), for each bunker:  
a) which type of goods TG (TG = 0,…,15),  
b) how many goods stored at the moment NG (NG = 0,…,15),  
c) auto maintenance of bunkers database DB_BNK, initial data – manually.  

**TS2**  
Control of the current status of storage bunkers and operational units (DB_BOU), for every bunker or unit:
a) available or unavailable,
b) maintenance of bunkers and operational units’ database DB_BOU, in case of data modification – send data to OC (initial data input – manually).

**TS3**
For received task \( TS = TS(TG, NG, BNWL) \) – check if goods \((TG, NG)\) can be loaded to the selected bunker BNWL:

a) if possible – continue,
b) if it is impossible to load to the selected bunker BNWL – send detailed information about the error to the OC, stop TS,
c) else – continue.

**TS4**
For received task \( TS = TS(TG, NG, BNWL) \) and DB_BOU – technical condition check of storage bunker and operational units on the goods transportation line:

a) check the technical basis of bunkers loading operation using database DB_TBBNK of the transportation line (which operational units must be active),
b) if there are any malfunctioning units on the line or their function is blocked by other malfunctioning units (defined according to the operational unit availability database),
c) if goods can continue to be transported – continue,
d) if the line is malfunctioning or blocked – send detailed information about the error to the OC, stop TS.

**TS5**
According to 1) received task \( TS = TS(TG, NG, BNWL) \), 2) positive result of current bunker free space control (TS3), 3) positive result of technical condition check of operational units on the goods transportation line (TS4):

a) initial start of required operational units and control of the correct initial start of operational units,
b) if no errors have occurred – continue,
c) if errors have occurred – run diagnostics and send data to the OC, stop TS.

**TS6**
Criteria for task completion \( TS = TS(TG, NG, BNWL) \), send information to the OC, enter data to bunker database DB_BNK.

4. **Conclusion**
The complex automation of enterprise's side lines for non-food dry bulk goods production is an urgent problem, because very often it is the weakest spot of such enterprises.

This problem can be solved by the side line complex automation integrated into the centralized enterprise control system on the basis of a single information space. To achieve this, key project objectives are formulated. In addition, the article describes a possible approach to implementation of such project on the basis of a standard structure of a finished goods warehouse.

**References**

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