Modernization of the automated control system for compound feed transfer

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Abstract. Rational use of the fodder supply, enrichment of fooder with probiotics and other nutrients can increase the efficiency of livestock and poultry farming. The increasing demand for compound feed stimulates not only the creation of new enterprises for their production, but also the intensification of production at existing enterprises. When introducing automation systems at enterprises for the animal feed production everywhere including Russia, a typical mistake is the automation of the main production process and the preservation of the auxiliary processes of loading raw materials and finished products' shipment at the mechanization level. The development of computer programs for the practical implementation of required control algorithms can be implemented in universal and special programming languages. As a result of this work, the general algorithms for managing the transferring processes of compound feed at the finished product area were structured. The main subtasks were highlighted, for which the solution algorithms were developed. The use of algorithms for solving the main problems made it possible to form a general algorithm for managing compound feed transfer at the finished product area. As a result, an algorithm for the automated control of feed distribution to consumers was obtained.

1. Introduction

Compound feeds for farm animals usually include refined and milled feed mixtures of plant and animal origin.

For the purpose of enrichment, vitamins, micro- and macroelements, enzymes and other components necessary for the normal growth and development of farm animals are added to them.

Their use allows not only to increase animal productivity (growth is usually 20-30%), but also to prevent their morbidity.

Rational use of fodder resources, enrichment of feed with probiotics and other nutrients can increase the efficiency of livestock and poultry farming [1-4].

The production of compound feeds in the world is showing steady growth. The only exception was a 1% decline in 2019 due to the African swine fever epidemic and a strong decrease in the number of their livestock, especially in the Asia-Pacific region.

The constant increase in the production volume of mixed fodders stimulates not only the creation of new enterprises for their production, but also the production intensification at existing enterprises.
through the automation of the main and auxiliary technological processes at them. Many of them were built during the Soviet era and reflect the level of mechanization and automation of that time. But over the past 30-40 years, the theory and practice of technological processes' automation have progressed far ahead.

The introduction of technical and technological innovations makes it possible to increase production efficiency [5–10]. When introducing automation systems at enterprises for the animal feed production in Russia, a typical mistake is the automation of the main production process and the preservation of the auxiliary processes of loading raw materials and finished products' shipment at the mechanization level. As a result, it is these auxiliary areas that turn into bottlenecks for these industries and limit the intensification of production.

2. Materials and methods

As noted above, the task is to develop such a structure of the information subsystem of the finished product area that would contain all the necessary information on the current state of its actuating devices. Let us first introduce the necessary notation.

Let us designate the finished products' hoppers through BN, in the numbers in the Automated process control system of the finished product section (ACS TP FPS) - through BNN. The total number of finished product hoppers will be denoted through BNUM.

Actuating devices are the following (Figure 1):

1) the bucket chain drive (vertical conveyor) lifting the finished product to feed it into the finished product hopper 10 (Figure 2.1), in the ACS TP FPS, bucket chains are designated as NR, their numbers - through NRN, the total number of bucket chains - through NRNUM (NRN = 1, ..., NRNUM),

2) the drive of the horizontal conveyor, through which the finished product is delivered to the finished product hoppers 10 after the bucket chain; in the ACS TP FPS, horizontal conveyors are designated GT, their numbers - through GTN (GTN = 1, ..., NRNUM),

3) the drives of the flow switches on horizontal conveyors are designated FS, the number of the flow switch for the BN hopper is designated as FSN (FSN = 1, ..., BNUM),

4) the drives of the top covers of the finished product hoppers BN are designated HC, the number of the cover drive for the BN hopper is designated as HCN (HCN = 1, ..., BNUM),

5) drives of the bottom rack and pinion gates of the finished product hoppers BN are designated GV, the number of the rack and pinion gate drive for the BN hopper is designated as GVN (GVN = 1, ..., BNUM).

Consider all types of actuating devices and the proposed display of their current state in the information subsystem.

I. Bucket chains NR (NRN = 1, ..., NRNUM).

1. The logical attribute NRTS is introduced to assess the current technical serviceability of the bucket chain. It is equal to 0 - in case of failure of the bucket chain and 1 - in case of its technical serviceability.

2. The logical attribute NREM is introduced to assess the current employment of the bucket chain during the loading operation. It is equal to 0 if the bucket chain is currently busy and 1 if the bucket chain is free. Table 1 contains this information, let us call it NR.

II. Horizontal conveyors GT (GTN = 1, ..., NRNUM).

1. The logical attribute GTTS is introduced to assess the current technical serviceability of horizontal conveyors. It is equal to 0 - in case of a malfunction of the conveyor and 1 - in case of its technical serviceability.

2. To estimate the current occupancy of the conveyor during the loading operation, we introduce the logical attribute GTEM. It is equal to 0 - if the conveyor is currently busy and 1 - if the conveyor is not busy. Table 2 containing this information will be called GT.
Figure 1. Actuating devices.

Table 1. NR containing information on the current state of bucket chains.

| NRN | NRTS | NREM |
|-----|------|------|
| 1   | 1    | 1    |
| ... | ...  | ...  |
| NNUM| NNUM1| NNUM2|

Table 2. Information on the current state of horizontal conveyors.

| GTN | GTTS | GTEM |
|-----|------|------|
| 1   | 1    | 1    |
| ... | ...  | ...  |
| NNUM| NNUM1| NNUM2|

III. BN hoppers and related actuators TR, FS, HC, GV.
1. To assess their current technical serviceability, the logical traits TRTS, BNTS, FSTS, HCTS, GVTS are respectively introduced.
2. The logical traits TREM, BNEM, FSEM, HCEM, GVEM are respectively introduced to assess their current engagement.

Table 3 contains this information, let is call it BN.

Table 3. Information on the current hoppers' state and related actuating devices.

| BNN | TRTS | TREM | BNTS | BNEM | FSTS | FSEM | HCTS | HCEM | GVTS | GVEM |
|-----|------|------|------|------|------|------|------|------|------|------|
| 1   | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |

...
If the actuating device is busy or technically faulty, then the corresponding trait is 0. If the device is free or technically sound, then the trait is 1.

IV. Plurality of actuating devices that ensure the loading of finished products into a given BN hopper. According to the applied transfer technology of mixed feed at the finished product area (Figure 2.1), the NR bucket chain is first switched on, then the TR conveyor, then the FS flow switch, then the HC top cover of the finished product BN hopper is opened.

Process chains NR → TR → FS → HC → BN is suggested to be specified in Table 4 BNL.

Table 4. Information on actuating devices used when loading finished products into a given hopper with a BNN number.

| BNN | NR | TR | FS | HC |
|-----|----|----|----|----|
| 1   | 1  | 1  | 1  | 1  |
| ... | ...| ...| ...| ...|
| BNUM| BNUM1| BNUM2| BNUM3| BNUM4|

V. The current hoppers' load. For each hopper with a BNN number, the following data is specified:

a) type of compound feed CFT, values CFT > 0 set the type of compound feed, value 0 means that the hopper is empty,

b) the mass of compound feed in the CFM hopper.

It is proposed to use Table 5 BNC to specify the hoppers' loading.

Table 5 BNC. Information on the current hoppers' load.

| BNN | CFT | CFM |
|-----|-----|-----|
| 1   | 1   | 1   |
| ... | ... | ... |
| BNUM| BNUM1| BNUM2|

Thus, the introduced tables NR, GT, BN BNL, BNC contain all the necessary information about the current technical serviceability, the employment of all actuating devices used in the ACS TP FPS, technological chains of hoppers' loading and their current load. They constitute the information subsystem of the finished product area FPS_INF = {NR, GT, BN BNL, BNC}.

Its proposed tabular presentation allows using standard database management systems (DBMS) to support the information subsystem of the FPS_INF finished product area.

VI. Communication of bucket chains with hoppers. For each bucket chain with NRN number, the hoppers BNN1, ..., BNN5 served by it are specified. It is proposed to use Table 2.6 NRB to set the connection between bucket chains and hoppers.

Table 6. NRB. Information about the connection of bucket chains with hoppers.

| NRN | BNN1 | BNN2 | BNN3 | BNN4 | BNN5 |
|-----|------|------|------|------|------|
| 1   | 1    | 1    | 1    | 1    | 1    |
| ... | ...  | ...  | ...  | ...  | ...  |
| NRNUM| NRNUM1| NRNUM2| NRNUM3| NRNUM4| NRNUM5|

Thus, the introduced tables NR, GT, BN BNL, BNC, NRB contain all the necessary information about the current technical serviceability, the engagement of all actuating devices used in the ACS TP FPS, technological chains of hoppers' loading and their current load. They constitute the information subsystem of the finished product area FPS_INF = {NR, GT, BN BNL, BNC}.
Its proposed tabular presentation allows using standard database management systems (DBMS) to support the information subsystem of the FPS_INF finished product area.

3. Results and Discussion

Let us consider a general algorithm for controlling compound feed transfer at the finished product area.

The general task of finished products' transfer from the vertical mixer 9 is as follows. The specified mass CFM of the specified compound feed type CFT must be loaded through the NRN bucket chain into the finished product hoppers (Figure 2). It is assumed that the loaded CFM does not exceed BNM_MAX - the capacity of one hopper.

Task input: a) bucket chain number NRN; b) mass of compound feed CFM; c) type of compound feed CFT.

Problem output: a) logical value L, equal to: 0 - loading is impossible due to occupancy or malfunction of actuating devices, 1 - loading is possible and successfully completed.

LOAD algorithm (NRN, CFM, CFT, L) for solving the general problem of compound feed transfer.

**Figure 2. Control algorithm (step 2).**

Step 1. Output value initialization:

Step 2. Preliminary check of the hoppers' contents associated with the bucket chain exit from the algorithm with a message about the occupancy and/or technical malfunction of the bucket chain hoppers

Step 3. Choosing the optimal hopper for loading

Step 4. Start of loading through the bucket chain NRN of the CFM mass of compound feed type CFT into the BNOPT hopper.

Activation of the NRN bucket chains' drives, TRN conveyor, FSN flow switch and BNOPT hopper HCN top cover.

Step 5. Current load monitoring.

The following actions are performed in the triggering cycle of the control device.

Step 6. Loading completion.

Step 7. End of loading.

Completion of the algorithm.
Algorithm for the distribution of compound feed to the consumer at the finished products' area

The consumer needs to get a given CFM mass of compound feed of a given CFT type.
Problem input: a) mass of compound feed CFM, b) type of compound feed CFT.
Problem output: a) logical value L equal to: 0 - loading is impossible due to lack of sufficient CFT-type compound feed mass, 1 - loading is possible and successfully completed.
Algorithm PR_LEAVE (CFM, CFT, L) of feed distribution to the consumer.

Figure 3. Control algorithm (step 3).

Step 1. Output value initialization:
Step 2. Checking the presence of compound feed type CFT in the hoppers. Formation of an array of hoppers filled with compound feed type.
Step 3. Determination of the optimal BNOPT hopper option for loading.
Step 4. Start of compound feed loading.
Step 5. Current control of compound feed loading.
Step 6. Completion of compound feed loading.
Entering the changed data on the hopper's loading.
Completion of the algorithm.

4. Conclusion
The use of SCADA systems allows to monitor the performance of certain technological processes in real time. This software is transferred to appropriate computing facilities. Its connection with the object of control and the operator is carried out in real time using special drivers.
Writing programs for the practical implementation of the necessary control algorithms can be implemented both in universal programming languages and in special languages. They are usually created in dedicated software development environments.
As a result of this work, the general algorithms for managing the transferring processes of compound feed at the finished product area were structured. The main subtasks were highlighted, for which the solution algorithms were developed.
The use of algorithms for solving the main sub-problems made it possible to form a general algorithm for managing compound feed transfer at the finished product area. As a result, an algorithm for the automated control of feed distribution to consumers was obtained.

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