Design principles of modern control systems for main ventilation fan installations

Design principles of modern control systems for main ventilation fan installations

V Yu Ostrovlyanchik, V A Kubarev, D E Modzelevsky, D A Marshev and N V Verigin

Siberian State Industrial University, 42 Kirova street, 654007, Novokuznetsk, Russia

E-mail: kubarev.sibsiu@list.ru

Abstract. In the paper, based on the analysis of the functional properties of control objects, the basic principles of automation of the fan installation are considered, the functional structure of the control object is given, the main functional connections of the controlling object with the distributed principle of controlling the objects of the fan installation are determined. The technique for developing a control system using the principle of modularity is proposed, which makes it possible to reduce the labor costs for the implementation and debugging of the system of technological automation and protection of the fan installation.

1. Introduction

Up to now, outdated automation and protection systems are being used at the main mine fans. The use of outdated automation equipment and control systems of the electric drive does not allow the fan installation to be integrated into the dispatching system, and, besides, it does not allow the required level of safety of the fan installation to be ensured.

The development of modern fan control systems will improve the quality of their operation and reduce the cost of repairs and maintenance.

Thus, the problems solution for designing modern control systems for fan installations, the definition of the basic design principles and the stages of designing control systems is important.

2. The proposed implementation

The purpose of this work is to develop the functional structure of the control systems for main ventilation fan installations based on the design principles of fan installation automation systems.

LLC “Scientific Research Institute of Automation and Electrical Engineering SibSIU” together with the Department of Electrical Engineering, Electric Drive and Industrial Electronics at SibSIU developed a fan control system. The system consists of separate autonomous modules, which allows, if necessary, the composition and functionality of the system to be changed [1]. The functional diagram of the fan installation is shown in figure 1.

The functional diagram (figure 1) presents:

- Controllig objects: operator (OP), operator workstation (OpW), FICS1 – fan installation control system No. 1, FICS2 – fan installation control system No. 2;
- Controlled objects for fan installation No. 1: synchronous motor (SM1), fan blades (WO1), guide vane (GV1), straightener vane (SV1), fan doors (FD1, FD2), with position sensors D_1 ... D_4, electromagnetic brake (EB1); for fan No. 2 SM2, WO2, GV2, SV2, FD3, FD4, EB2 accordingly.

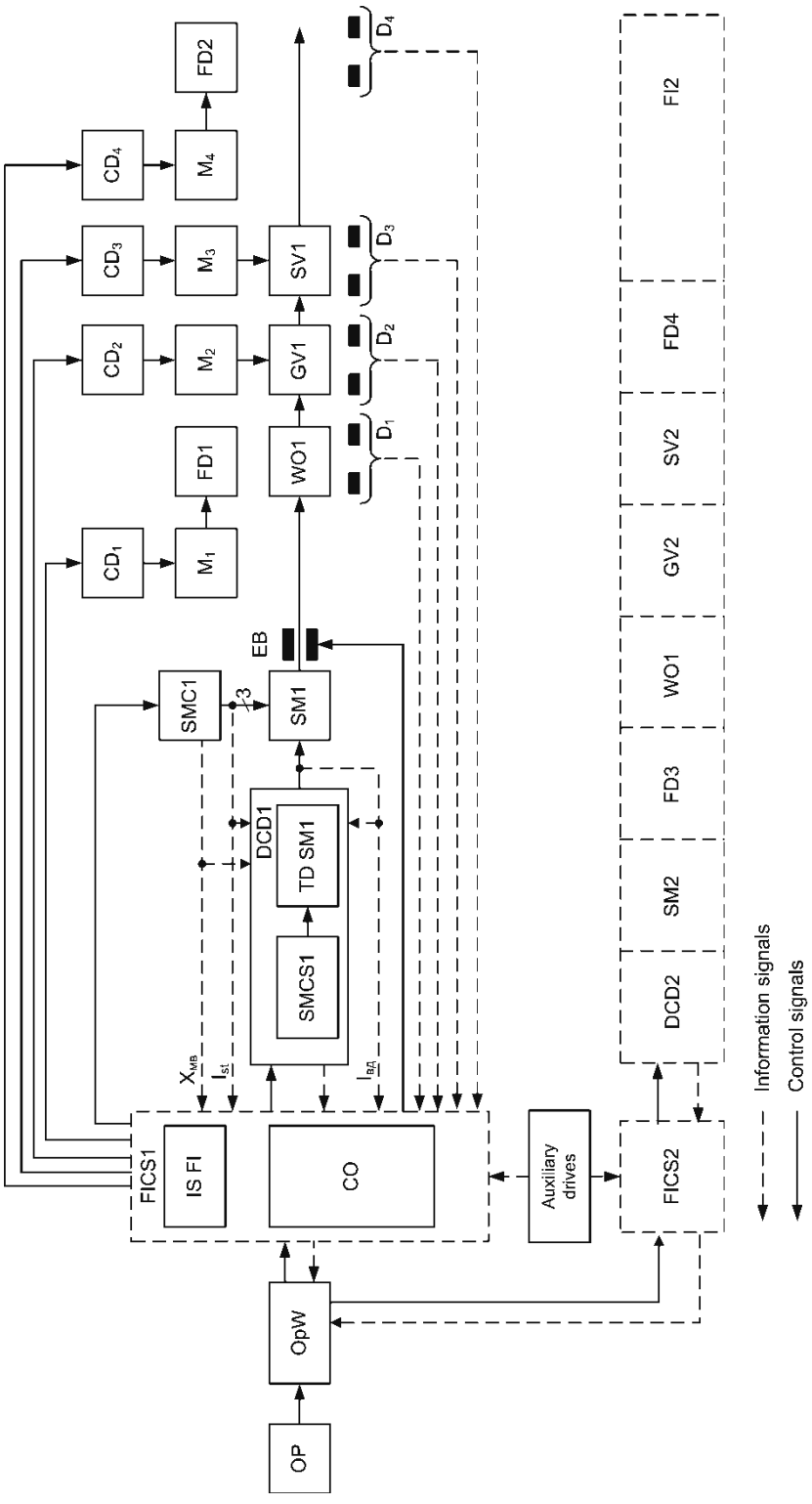

Figure 1. Functional diagram of the fan control system.

According to the functional features in the diagram in figure 1, the following types of control devices can be distinguished. Single-position devices are devices that have only two conditional states: “on’ and “off”. Such a device can include a synchronous motor, the starting mode of which is carried out by switching on by means of a high-voltage switch and automatic excitation control. This operation is performed automatically by the synchronous motor excitation system, all protections and interlocks are performed directly in the control system. Therefore, the synchronous motor as a whole can be considered as a controlled element [3], controlled switching on, that is, by signaling: “on”, “off”, “reverse” (figure 2).

The controlled values: angular speed and parameters of the synchronous motor (ω – speed, I_{rot} - rotor current, I_{st} – stator current).

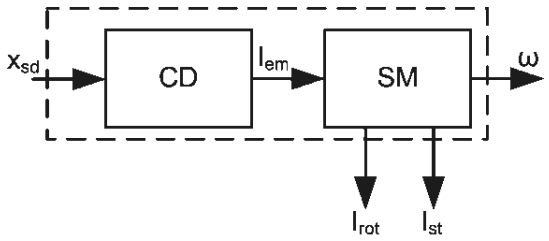

Figure 2. Functional diagram of the synchronous motor as a single-position device.

To the second type of devices – two-position devices, one can refer devices with two output states, for example, doors (figure 3).

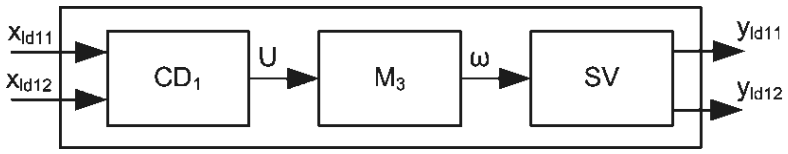

Figure 3. Functional diagram of the two-position device.

For this type of device, two states of the mechanism can be distiguished, for example: “open" $y_{ld11} = 1$, $y_{ld12} = 0$ and “closed” $y_{ld11} = 0$, $y_{ld12} = 1$. Accordingly, the control signals “to open” $x_{ld11} = 1$, $x_{ld12} = 0$ and “to close” $x_{ld11} = 0$, $x_{ld12} = 1$.

To the third type belongs multi-positioning devices: guiding and directing devices (figure 4).

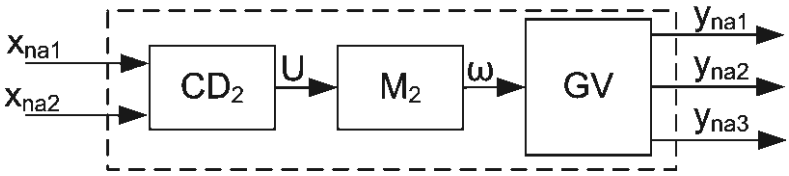

Figure 4. Functional diagram of the multi-position device.

For this type of device, there are also one or more intermediate states of the actuator between the two end positions, for example between the positions y_{na1}, and y_{na3}, the intermediate position y_{na2}.

The functional diagram of the control object of the fan installation is given in figure 5, information and control signals of the fan control system are presented in table 1.

Table 1. Controlling and controlled signals.

No.	Mechanism	Functional features	Control signals		Controlled signals and output values	
			Designation	Type	Designation	Type
1	Doors No.1…No.4	Two positions 1. Closed 2. Open	x_{ld11} — No.1 to close x_{ld12} — No.1 to open x_{ld21} — No.2 to close x_{ld22} — No.2 to open x_{ld31} — No.3 to close x_{ld32} — No.3 to open x_{ld41} — No.4 to close x_{ld42} — No.4 to open	Discrete	y_{ld11} — No.1 closed y_{ld12} — No.1 open y_{ld21} — No.2 closed y_{ld22} — No.2 open y_{ld31} — No.3 closed y_{ld32} — No.3 open y_{ld41} — No.4 closed y_{ld42} — No.4 open	Discrete
2	Synchronous motor	Three positions 1. Forward 2. Stopped 3. Reverse	x_{sd1} — MB work x_{sd2} — MB reverse	Discrete	y_{sd1} — MB in work y_{sd2} — MB in reverse I_{rot} – rotor current I_{st} – stator current ω – speed	Discrete Analog
3	Directing vanes	Two positions 1. Open 2. Closed	x_{sa1} — to close x_{sa2} — to open	Discrete	y_{sa1} — closed y_{sa2} — open	Discrete
4	Guide vanes	Three positions 1. Work 2. Closed 3. Reverse	x_{na1} — to close x_{na2} — to open	Discrete	y_{na1} — closed y_{na2} — open y_{na3} — reverse	Discrete
5	High-pressure pump station	Two positions 1. Switched on 2. Switched off	x_{ms1} — to switch off x_{ms2} — to switch on	Discrete	y_{ms1} — switched off y_{ms2} — switched on	Discrete
6	Brake unit	Two positions 1. Braked 2. Unbraked	x_{et1} — to unbrake	Discrete	y_{et1} — braked y_{et2} — unbraked	Discrete

The control device includes the following modules:

1. OP – operator;
2. OpW – the console (workstation) of the operator;
3. RRU – the unit of reset and availability control unit. Checks the condition and availability of all mechanisms;
4. RMRRU – the unit of reset and availability control unit in the reverse mode. Cheks the condition and availability of all mechanisms for the reverse mode;
5. RPU – block for reverse preparation. Prepares the reverse of the fan installation;
6. SM – synchronous motor;
7. SMCD – synchronous motor control device;
8. IS FI - information system of the fan installation.

The basic design principle of a functional diagram is based on the simulation of the process of manual control. The process of starting the fan installation can be represented in the following sequence:

1. Selection of the fan installation to be put into operation.

2. Selection the type of control “manual”/”automatic” and the operating mode for the fan installation: “work”/”reverse”.

3. Check the condition and the required initial position of all mechanisms.

4. Bringing the mechanisms in the required starting position.

5. Fixing the initial state of the mechanisms (“readiness”) and start-up.

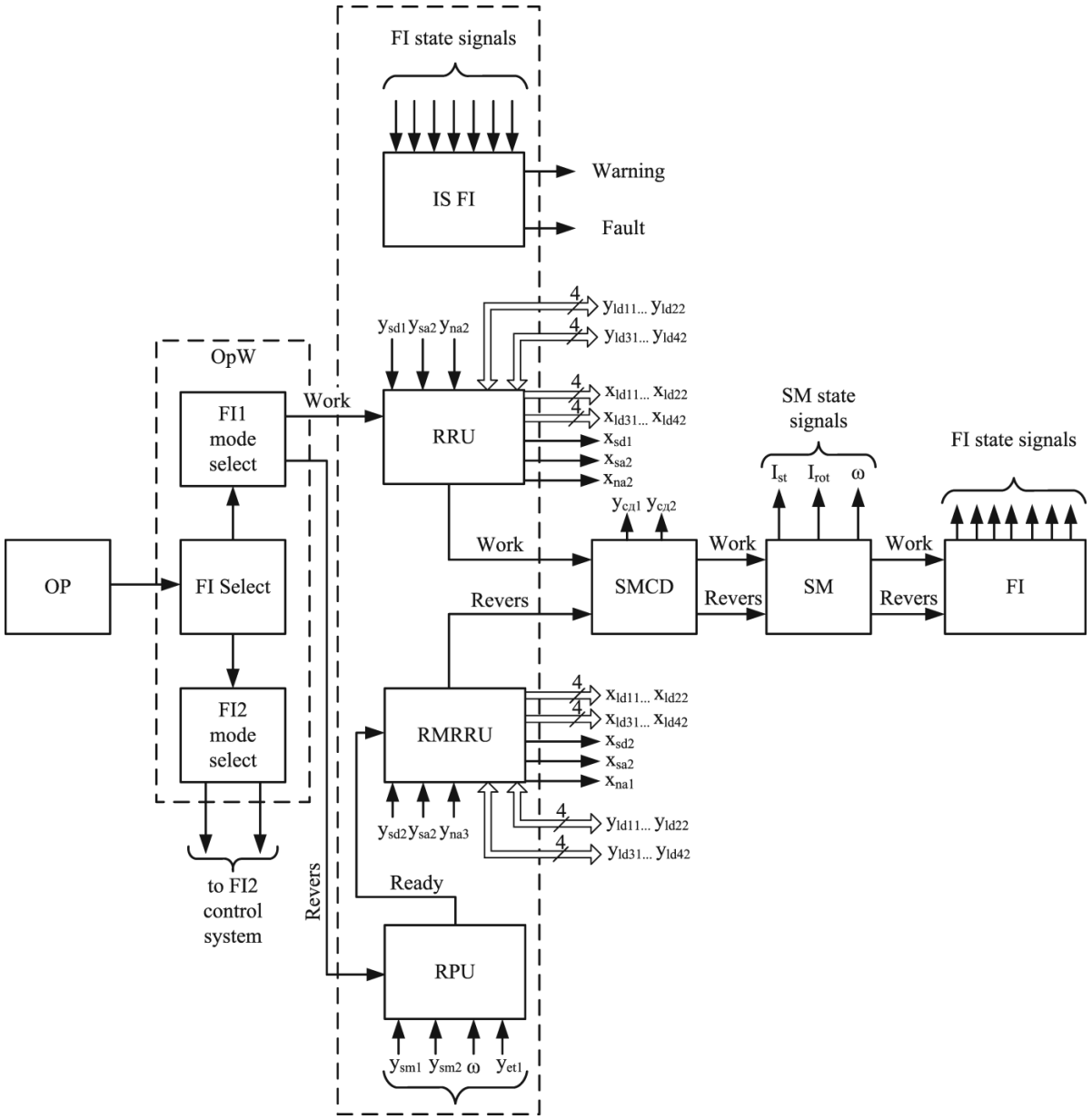

Figure 5. Functional diagram of the fan control device.

Thus, when designing functional structure of the controlling object of the fan unit, the following algorithm can be used:

1. Analysis of functional characteristics of individual elements in the fan installation with the identification of the type of control actions and information about the state of the mechanism;

2. Analysis of the processes associated with the preparation of the mechanism to work and the set up of initial states;

3. Identification of the features of functional structure and system modules that imitates the process of “manual control” (preparation for work – bringing all mechanisms into the initial state, readiness assessment).

4. The structure and functions of the information-control system of the fan installation are determined.

3. Conclusion

The proposed approach to design of a digital control system for a fan installation makes it possible to simplify the automation process considerably, since it allows control modules of a system having the features of standardization and operational independence to be obtained. For example, in case of necessity to control the performance without modifying the remaining modules, an additional module with its own control channel can be added. Each module has the flexibility and the ability to add control functions.

References

[1] Ostrovlyanchik V Yu et al 2018 *Bulletin of KuzSTU* **1** 139–148
[2] Babak G A et al 1982 *Mine Fan Installations of the Main Ventilation. Reference book* (Moscow: Nedra) p 296
[3] *Control Theory. Terminology* 1988 ed B G Volik issue 107 (Moscow: Nauka) p 56