Project development of a "smart" premise system for pig keeping

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Abstract. The economic efficiency of intensive animal husbandry on an industrial basis depends on the rational animal keeping, which is largely determined by the availability of optimal microclimate in the premises. Whatever breed and pedigree qualities animals possess, they are unable to maintain health and display their potential hereditary productive abilities without creating the necessary microclimate conditions. In the period of 2018-2020, a survey of 11 farms in Perm Krai was carried out, where respiratory, digestive, skin diseases were found, in some cases stress was observed in animals. The cost of heating livestock premises is generally much lower than losses from murrain, reduced productivity, and feed overruns. Physical properties of the air environment are unstable factors and are subject to large fluctuations. To optimize the microclimate in livestock premises, an algorithm program for computers was developed, which will allow to create a system that provides optimal conditions for keeping and maintenance of animals and improve life safety on livestock farms. In this regard, to improve the conditions of calves and cows' keeping, a project for managing microclimate parameters on farms in the conditions of Perm Krai has been developed. Microclimate management system was developed on the basis of: the Order of the Ministry of Agriculture of the Russian Federation dated October 21, 2000 No. 621 "On approval of Veterinary rules for the maintenance of pigs for the purpose of their reproduction, cultivation and sales." Monitoring is based on automated analysis and regulation of microclimate parameters' indicators. The software and hardware implementation were done on Omron PLC.

1 Introduction

Breeding pigs with a high growth rate requires maintaining comfortable microclimate parameters in pigsties [1,2]. Even though a regulated microclimate is created in the premises of pig complexes, it still does not always correspond to the optimal values. Such

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deviations from the recommended norms can be due to the time of year, environmental and climatic conditions, building structures, features of keeping, as well as functioning efficiency of systems ensuring optimal zoohygienic parameters [3]. Numerous studies have found that unfavorable keeping conditions are the cause of significant losses of young animals (up to 40%) and lead to a decrease in productivity (by 20 -30%), which is why there is an overconsumption of feed, a reduction in the life of animals [4,5]. The microclimate study based on the laws of mass and energy conservation is studied in the work [6], the influence of microbial and bacterial flora on the vital activity of pigs is described in the work [7]. The article [8] is devoted to simulation models' development of microclimate control. This work is devoted to the development of a microclimate control system based on the use of the Omron controller [9,10].

2 Equipment and devices used in studies

The methodical basis for the development of a microclimate management project in pig keeping premise is Order No. 621 dated October 21, 2020. “On approval of Veterinary rules for the maintenance of pigs for the purpose of their reproduction, cultivation and sales.” The hardware components of the system are: CP1 PLC programmable logic controller (14 I/O module powered by AC source), microclimate parameters sensors, gas analyzer sensors and equipment actuators. “CX-Programmer” software was used as software tools for programming.

3 The results of the study

3.1 Requirements for physical and chemical air parameters in pig breeding premises

According to the veterinary rules for pig keeping, pig stalls are divided into: (a) pigsties for young pigs and fattening; (b) pigsties for barren dams, enceinte sows, and breeding boars; (c) pigsties for nursing sows with piglets. Indicators of the microclimate in the premise depend on the season and are characterized by physical and chemical indicators: T - temperature, W - humidity, V - air movement speed; maximum permissible concentration of harmful gases: NH_3 — ammonia and H_2 S — hydrogen sulfide. The enlarged microclimate control scheme is shown in Figure 1. A description of the sensors (input signals) is given in Table 1.

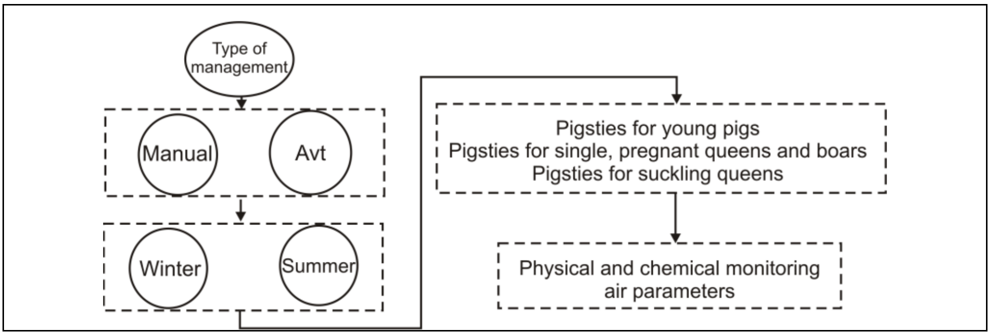


Fig. 1. Enlarged microclimate control scheme.

https://doi.org/10.1051/e3sconf/202125408029

Table 1. Input signals.

No.	Signals	Designator		Memory address
Physical parameters of the air environment				
1	Air flow	VO	Operational	D400
		VL	Left border	D401
		VR	Right border	D402
2	Relative air humidity	WO	Operational	D500
		WL	Left border	D501
		WR	Right border	D502
3	Air temperature	TO	Operational	D600
		TL	Left border	D601
		TR	Right border	D602
Chemical parameters of air environment (Maximum permissible concentration)				
4	Ammonia	NH3	Operational	D10
			Right border	D12
5	Hydrogen sulfide	H2S	Operational	D20
			Right border	D22
6	Emission time	t		0.05
General control signals				
7	Season of the year	SW		2.00
8	Manual	HA		3.00

Output distribution (equipment drives control) is given in Table 2.

Table 2. Output signals to the equipment drive.

No.	Signals	Designator	I/O block
1	Heat gun	Y1	100.03
2	Sprayer	Y2	100.01
3	Air conditioning	Y3	100.02
4	Fan	Y4	100.04
5	Hazardous state	Z0	100.05
6	Gas emission	Z1	100.06

3.2 Logical equations development of equipment control

3.2.1 Monitoring physical parameters of the air environment

The flowgraph of the algorithm for monitoring physical parameters of the air environment on the example of air temperature regulation is shown in Figure 1. The flowgraph contains the trigger element required to supply power to the drive during the transition process.

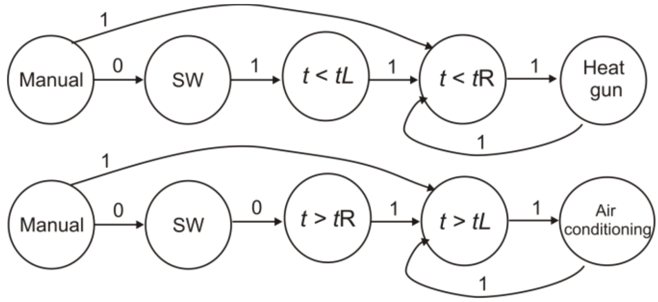


Fig. 2. The flowgraph of the air temperature control algorithm for the seasons of the year.

The logical equations of equipment drive control are shown in table 3.

Table 3. Output signals to the equipment drive.

	Equation	**Drive**
1	$\left(HA \vee \left(\overline{HA} \cdot SW\right)\left(HG \vee \left(TO < TL\right)\right)\right) \cdot \left(TO < TR\right) = HG$	HG (Heater gun)
2	$\left(HA \vee \left(\overline{HA} \cdot \overline{SW}\right)\left(AC \vee \left(TO > TR\right)\right)\right) \cdot \left(TO > TL\right) = AC$	AC (Air conditioning)
3	$\left(HA \vee \left(\overline{HA} \cdot SW\right)\left(WA \vee \left(WO < WL\right)\right)\right) \cdot \left(WO < WR\right) = WA$	WA (Sprayer)
4	$\left(HA \vee \left(\overline{HA} \cdot SW\right)\left(VT \vee \left(VO < VL\right)\right)\right) \cdot \left(WO < VR\right) = VT$	VT (Fan)

3.2.2 Chemical parameters monitoring of the air environment

Manure is formed with the vital activity of pigs, which can be a source of hydrogen sulfide and ammonia with a sharp odor. Exceeding the maximum permissible concentrations (MPC) can cause animal poisoning. To develop an alert for the presence of high harmful gases concentrations in the air, monitoring of the excess MPC time was introduced to alert personnel about an adverse situation. The validity table for gas concentration monitoring is shown in table 4.

Table 4. Validity table of gas concentration monitoring.

Signals			**State**	
H2S	NH3	t	Hazardous (Z0)	Gas emission (Z1)
0	0	0	0	0
0	0	1	0	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	1	0
1	1	1	0	1

To obtain the logical equations of gas emission monitoring, minimization was carried out and the following expressions were obtained

$\bar{t} \cdot \left(NH3 \vee H2S\right) = Z0$	Hazardous state
$t \cdot \left(NH3 \vee H2S\right) = Z1$	Gas emission

3.3 Ladder diagrams composing and simulation modelling

For the preparation of ladder diagrams, relay-switching logic was used. The mnemonics of the scheme is shown in Figure 3.

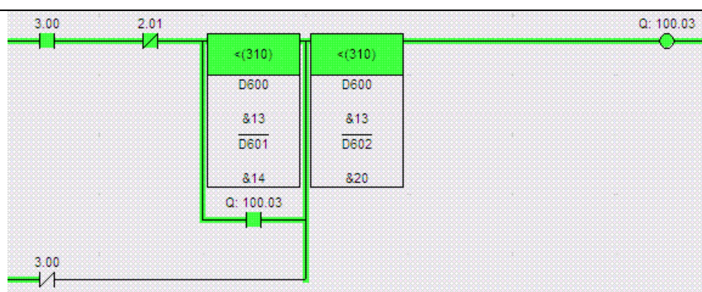
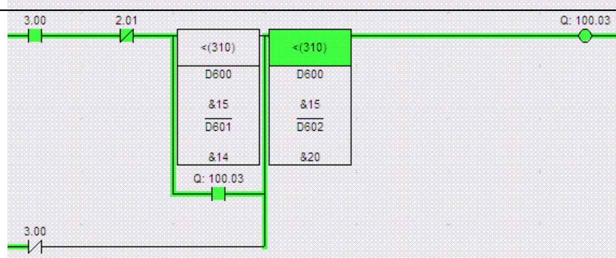
Rung	Step	Instruction	Operand
0		'	
	11	LD	3.00
	12	ANDNOT	2.01
	13	LD<(310)	D600
			D601
	14	OR	Q: 100.03
	15	ANDLD	
	16	ORNOT	3.00
	17	AND<(310)	D600
			D602
	18	OUT	Q: 100.03
1		'	
	19	LD	3.00
	20	AND	2.01
	21	LD>(320)	D600
			D602
	22	OR	Cond
	23	ANDLD	
	24	ORNOT	3.00
	25	AND>(320)	D600
			D601
	26	OUT	Cond
2		'	
	27	LD	3.00
	28	ANDNOT	2.01
	29	LD<(310)	D500
			D501
	30	OR	Q: 100.01
	31	ANDLD	
	32	ORNOT	3.00
	33	AND<(310)	D500
			D502
	34	OUT	Q: 100.01

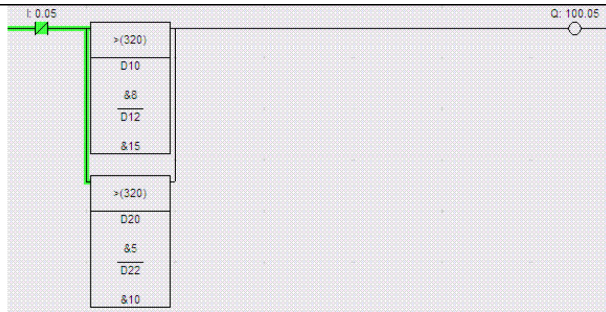
Rung	Step	Instruction	Operand
3		'	
	35	LD	3.00
	36	ANDNOT	2.01
	37	LD<(310)	D400
			D401
	38	OR	Steam
	39	ANDLD	
	40	ORNOT	3.00
	41	AND<(310)	D400
			D402
	42	OUT	Steam
4	43	LDNOT	I: 0.05
	44	LD<(310)	D10
			D12
	45	OR<(310)	D20
			D22
	46	ANDLD	
	47	OUT	Q: 100.05
5	48	LD	I: 0.05
	49	LD<(310)	D10
			D12
	50	OR<(310)	D20
			D22
	51	ANDLD	
	52	OUT	Q: 100.06

Fig. 3. Mnemonic circuits blocks.

To check the correctness of the scheme, simulation modelling (Table 5) was carried out.

Table 5. Simulation modelling.

Status description	**Simulation modelling**
Operational temperature less than the left border, heat gun running	
Operational temperature exceeded the left border, heat gun running	

Ammonia and carbon dioxide concentrations did not exceed MPC	

4 Conclusions

The article analyzed the air requirements of livestock premises for pig keeping based on the Order No. 621 dated October 21, 2000 of the Ministry of Agriculture of the Russian Federation. The analysis and synthesis of logical equations for monitoring and maintenance of permissible physical and chemical parameters of the air environment was carried out. Simulation modelling was carried out, which showed positive results of the software operation.

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