Robotic control system for particles size distribution of industrially produced mineral fertilizers

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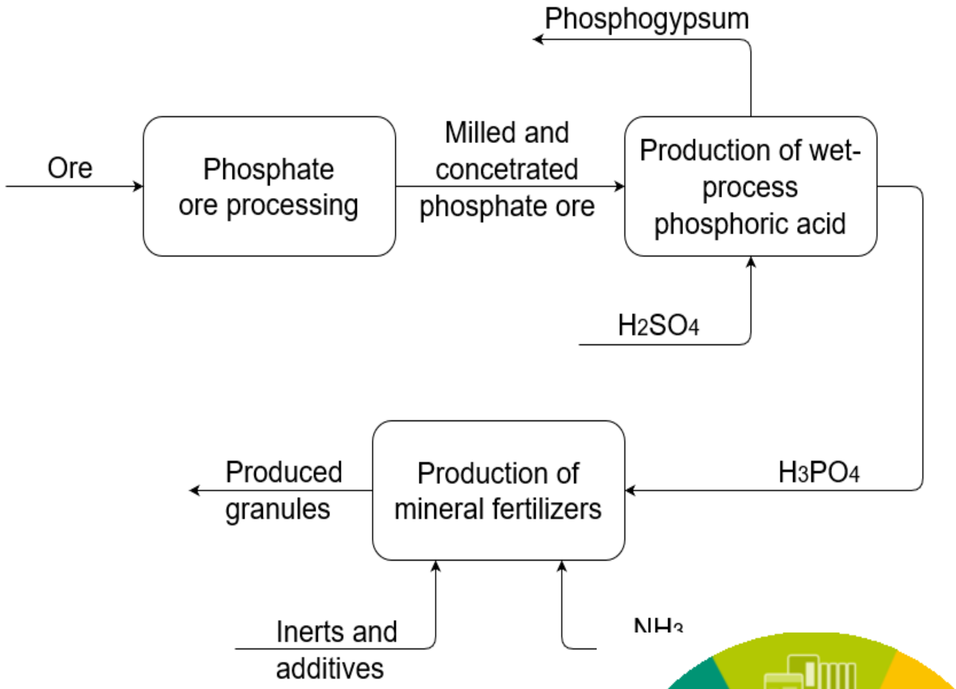
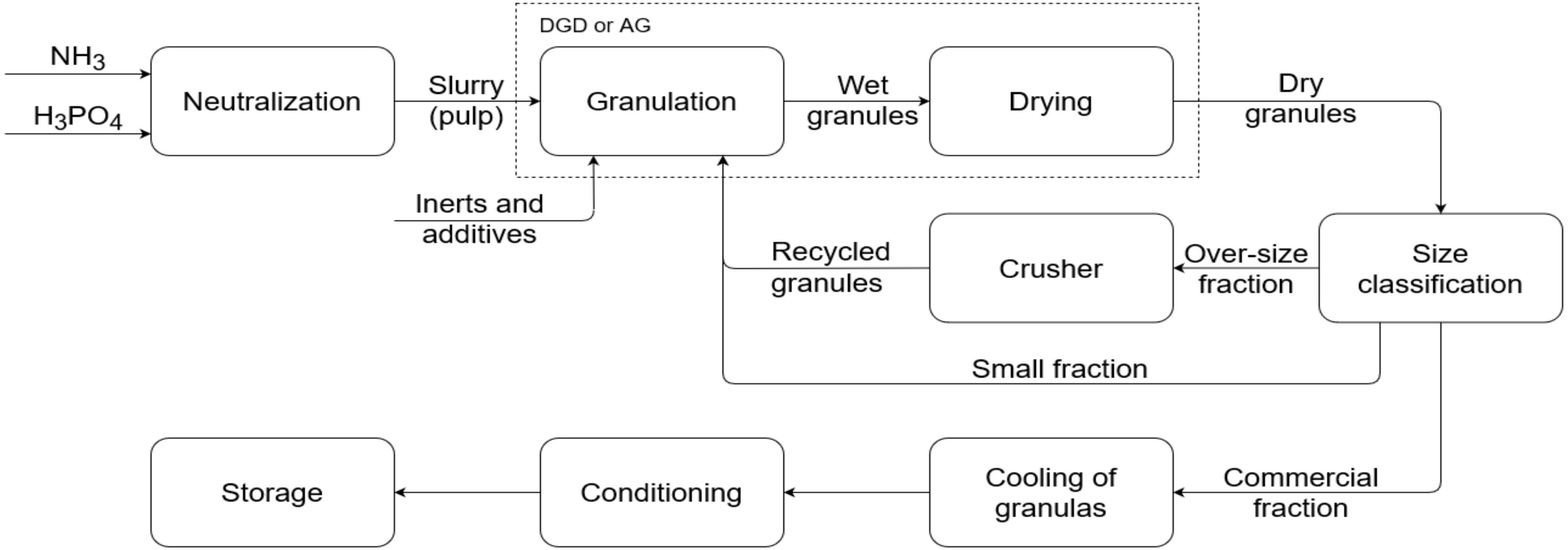
1. Mineral fertilizers and particle size

1. Mineral fertilizers and particle size. The mineral fertilizer industry



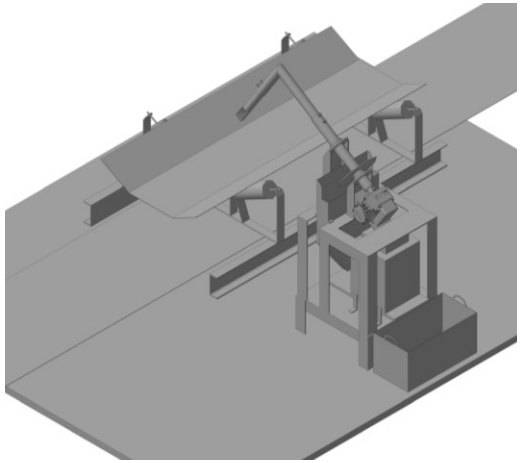
- The **mineral fertilizer production** in the World and in Russia is a fast-growing industry with a migration to industry 4.0 (decentralization of manufacture and flexible quality control of products).
- We consider the production of phosphorus-containing mineral fertilizers, which is a complex process with several facilities.
- Each of these complexes are a self-sufficient production, with they own SCADA systems. However, all the inaccuracies and failures in all of these complexes affect the quality of the **final product - the granular mineral fertilizers**.

1. Mineral fertilizers and particle size. The quality of the produced products

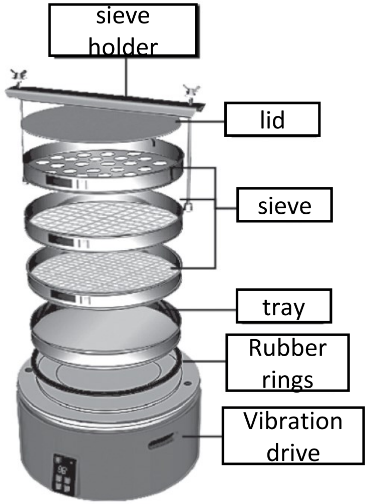


Let consider the production of granular phosphorus-containing mineral fertilizers at JSC "Apatite" (the main production part are shown on the figure). One of the most important quality parameters is **the particle size distribution** of fertilizer, which reflect the total industry process (the technological processes, agronomic effect, sample preparation for analyses, etc.).

1. Mineral fertilizers and particle size. Objects and existing methods



The purpose of this work is to **develop and test the robotic control system for particles size distribution of industrially produced mineral fertilizers.**



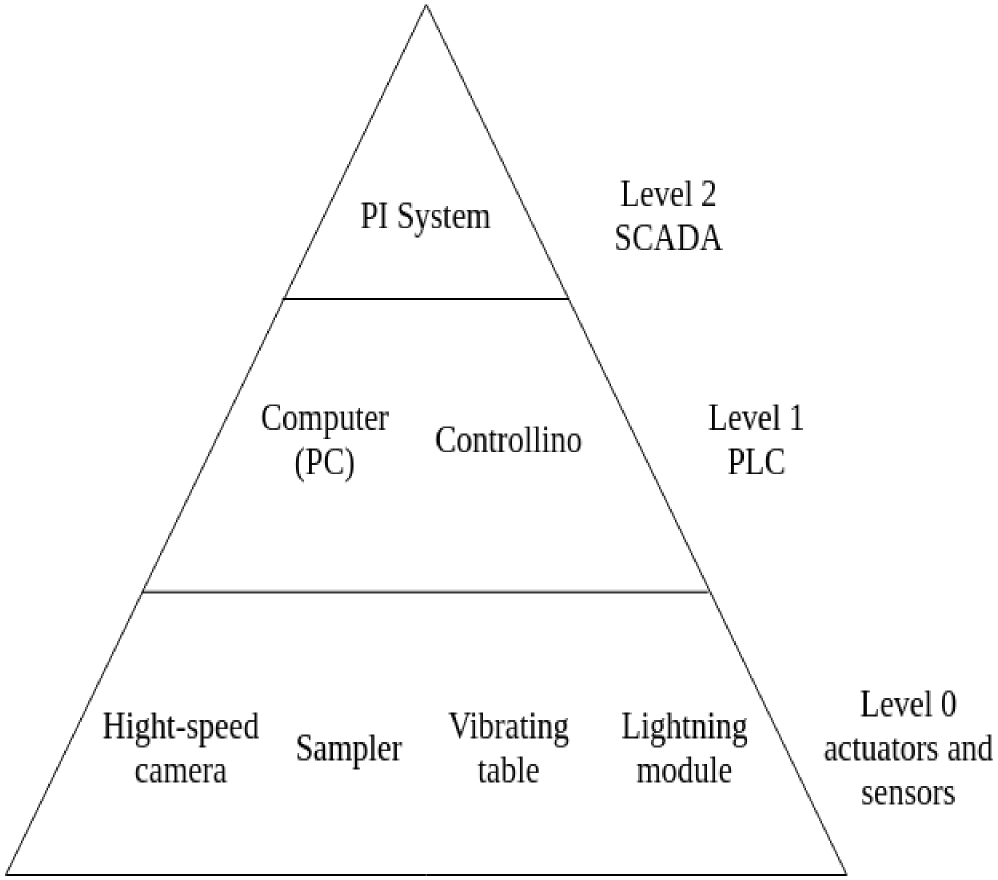
The existing methods have a number of drawbacks.

- *The sieve analyses* (cannot provide continuous control of the particle size distribution and highly depends on the shape of the particles).
- *The laser light scattering* (LLS, fundamental and highly accurate method of analysis; limited by the size of the studied particles and cannot estimate the shape and the colour).
  - *The optoelectronic control* (is the most universal; strongly depends on external measurement conditions of illumination, e.g. gradient, brightness and temperature).

Until now, there is no such equipment, which could provide online control in industrial conditions with reasonable price and high automation level.

2. The robotic control system

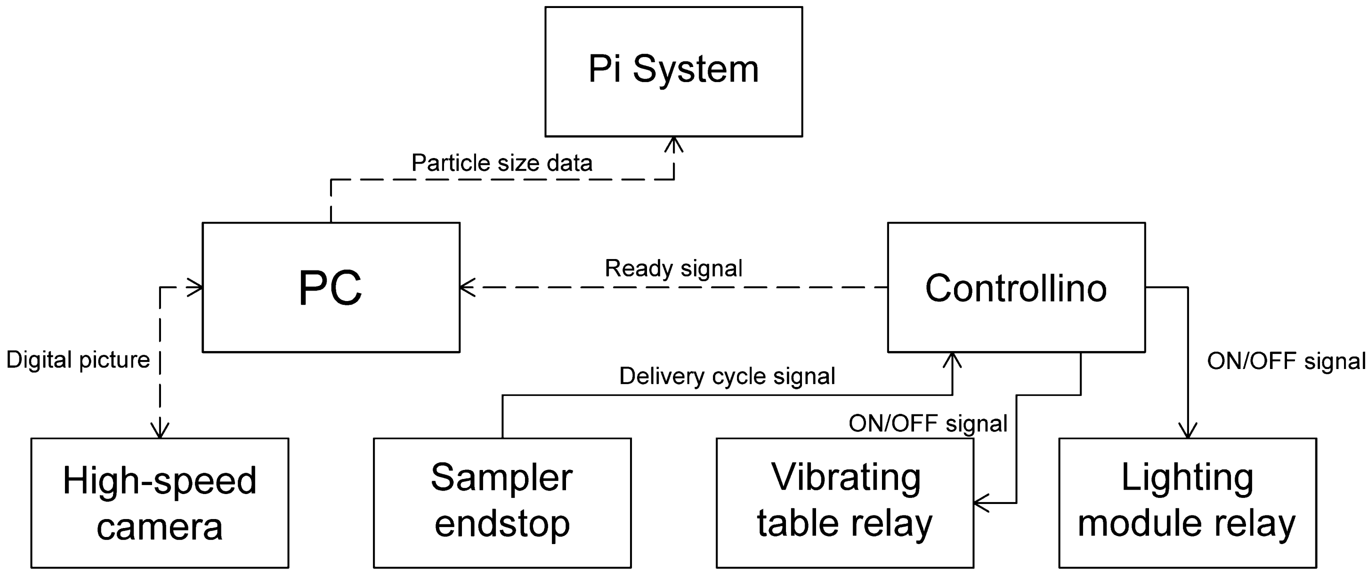
2. The robotic control system. Automation level



The developed **automatic granulometric system (AGS)** consists of 6 main components.

1. Sampler, which is based on a Single-turn Electrical Actuator (SEA).
2. Vibrating table (is based on a special vibro-magnets).
3. LED lighting assembly.
4. High-speed digital camera.
5. Controllino (Arduino-compatible PLC).
6. PC, which is runs a Linux operating system with an analysis software. It processes digital pictures from camera to calculate particle size, then creates a data file and sends it to the factory SCADA system.

2. The robotic control system. Main approach



If an error occurs, the information is output to the SCADA, and the computer tries to fix the problem or goes into standby mode.

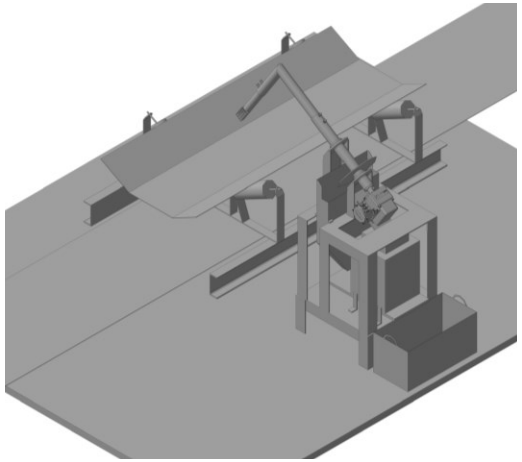
To represent the **flow of data and signals** in AGS we can use structural diagram (functional algorithm of a system).

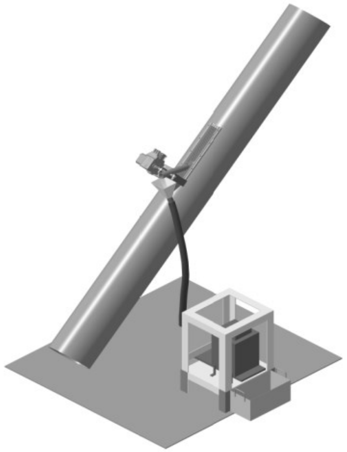
Features of system:

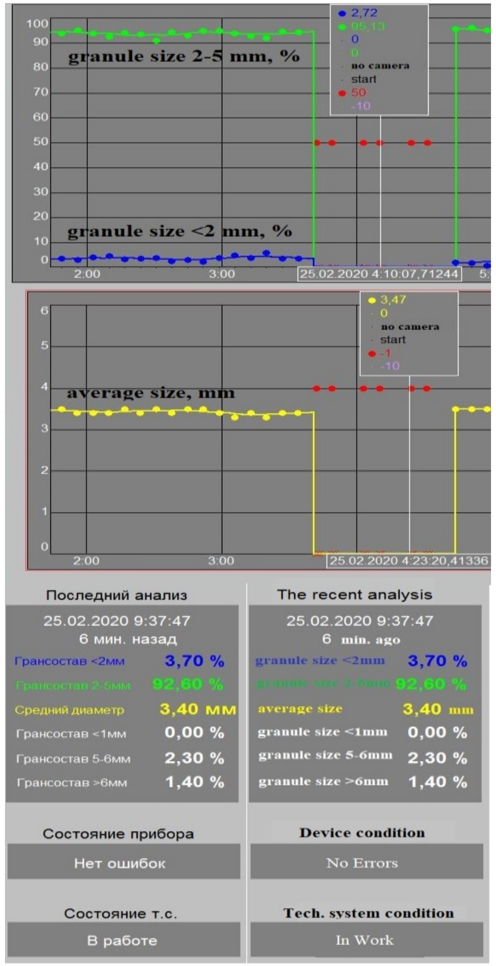
- self-diagnostic;
- low analysis time (start from 3 minutes);
- different instrument implementation (conveyer belts or pipes).

3. Practical implementation of the system

3. Practical implementation of the system. Workshops implementation







Industrial testing of the described system was carried out from 12.2018 to 03.2020, as a result of which **both systems were accepted by JSC “Apatit”** for further operation:

- diagnostic data and particle size distribution displays in SCADA online every 7 minutes;
- data of the colour and shape (sphericity) of the granules are stored locally on the AGS;
- in the last 5 months the system has not stopped for more than 3 hours.

3. Practical implementation of the system. Statistics.

Table 1. Statistical parameters of AGS operation.

	Workshop №1 (conveyor)			Workshop №2 (pipe)		
	fraction < 2 mm, %	fraction 2-5 mm, %	average granule size, mm	Fraction < 2 mm, %	fraction 2-5 mm, %	average granule size, mm
Average	4.85	95.14	2.96	13.75	86.02	2.86
Average square deviation	1.53	1.54	0.09	6.83	6.62	0.19
Number of self-diagnostic messages	111			49		

Table 2. Absolute deviation of AGS from laboratory methods of analysis (Camsizer P4).

	Workshop No. 1 (conveyor)	Workshop No. 2 (pipe)
fraction < 2 mm, %	1.93	3.29
fraction 2-5 m, %	2.22	2.90
average pellet size, mm	0.26	0.18

4. Conclusion

4. Conclusion

1. The robotic method of optoelectronic control of complex mineral fertilizers in industrial conditions was carried out.
2. General schemes of mineral fertilizers production were described.
3. Online control of granulometric composition, color and granule shape factor was provided.
4. The general schemes of equipment and software of the developed system were given.
5. Interrelation between the robotic system and the SCADA was shown.
6. The statistical characteristics of the proposed robotic system (mean and standard deviation) for two types of production were studied.
7. The obtained results were compared with similar laboratory devices for particle size distribution control (Camsizer P4).

Thank you!

Please do not hesitate to contact me directly

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- Author contribution.

1. Dmitriy Yunovidov – software and analytic expert, development of an idea and project, writing software, support of manufacturing and implementation of the device, writing scientific literature.
2. Kirill Menshikov – automation expert, improvement of robotic system and help in writing scientific literature.
3. Elizaveta Sidorova – fertilizer industry description and help in writing scientific literature

For experimental data do not hesitate to contact me: DVYunovidov@gmail.com