Automated Control Scheming of Granary Operating Procedures

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ABSTRACT— ***Due to the increased corn growing there is a problem of grain storage in remote areas. Modern control schemes do not allow controlling of operating procedures of grain storage in off-line mode. The problem of unmanned control of grain storage still remains of current interest. This article describes schemes of granary monitoring and automated control operating procedures to be applied at an innovative granary.***

Keywords— automated control schemes, innovative granary, programmable logic controller, operating procedures.

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1. INTRODUCTION

Eventually any production faces the necessity of automation processing in order to improve product quality and marketability. In this connection the agricultural industry is of no exception to be renovated speaking about granary automation in particular. Granary is a facility for storage of grain and bringing it to marketable conditions. Granary is a highly mechanized structure performing several operating procedures [1]. One of the principal means to reduce the cost of grain storage and processing is to introduce integrated automation for all the procedures.

Currently the main directions of automation are the following [2]:

– introduction of computer-controlled automated systems at grain-processing enterprises and granaries instead of relay control systems that are still used at many enterprises of the industry;

– installation of modern metering systems i.e. strain-gauge measuring sets connected to the unified automated system of grain accounting that significantly reduces human influence and improves accuracy of measurements;

– replacement of outdated temperature measurement systems being used at grain elevators and granaries by modern ones that underwent calibration certification;

– equipping of process sections with up-to-date facilities of automation, and control of quality performance of grain and its derivatives.

The above mentioned measures shall help to introduce automation of the industry. They have been partly implemented in modern granaries manufactured in China but this equipment consists only of monitoring systems for high and low grain loading, multipoint temperature transmitters for continuous monitoring of grain temperature at an interval of 2 m, and ventilation control system for grain cooling [3]. The sectional granaries provided by Italian TECNOIMPIANTI [4] are also not fully automated as they are only equipped with automatic control systems of loading, distribution, unloading, ventilation, temperature and moisture control.

There are some CIS companies that are engaged in designing and supplying the components for automation systems of granaries [5-7] but their technical solutions are limited to a narrow range of tasks and do not exclude "human influence" in the management process. Taking all the aforesaid into consideration we conclude that the proposed systems of granary automation and processing of grain are not effective enough.

The main objective of this research work is to design schemes of integrated control and management of operating procedures at the granaries of innovative type. This research work is funded by a grant of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan.

High performance, HR optimization, monitoring of the operations as well as troubleshooting and identification of emergency situations in their early stages can be achieved with the right approach to the control schemes. That is why the detailed study of the process flow is very important part of this research.

The testing object of the proposed system of remote monitoring and control is the granary of innovative type. The trial model of such granary was created as a part of previously conducted research and is situated at the agrobiological station of the NKSU named after M. Kozybayev. This sample granary has a capacity of 200 tons and is equipped with independent power source (wind power unit), innovative horizontal silos and automated management system of grain storage. See Figure 1 for this model.

Figure 1: Sample granary of innovative type

The testing model of granary is made of inclined metal sheets. The inclined walls are designed to deliver grain to the bottom conveyor. If it is necessary the tank can be increased lengthwise by adding sections. Each additional section is a monoblock unit with a separate automation set that should be connected only to the main scheme of the device automation.

The granary consists of horizontal silos. This reduces the construction cost, improves quality, increases storage time of grain, helps to reduce grain cost and to increase its marketability [8].

2. GRAIN LOADING/UNLOADING PROCEDURE

The distinguishing feature of the innovative horizontal silo is the way of grain unloading from the silo [9]. Here the conveyor for unloading grain is inside the silo, not under it, and it does not require additional underground floor. Figure 2 shows the grain unloading.

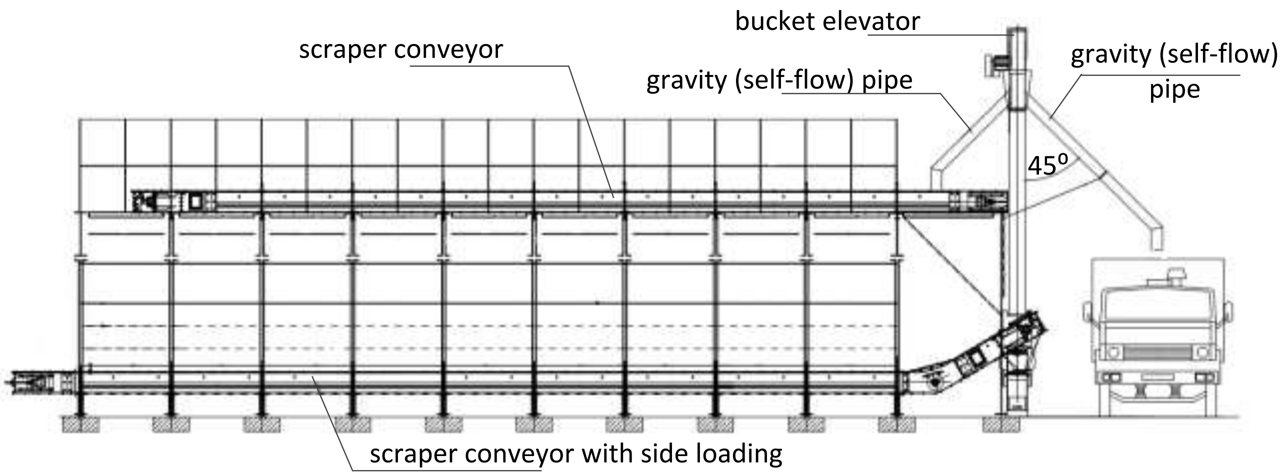

Figure 2: Grain unloading

Ready-to-storing grain is unloaded into the unloading pit. The grain gets down to the elevator through an intake spout of a screw feeder. In turn, the elevator delivers grain to the upper conveyor which fills the silo. In the granary, under the point of loading, there appears a spacing of impurities. So after the loading is done this grain with piled-up impurities is just removed for re-cleaning. It is worth noting that during one unloading operation only about 5% of grain is being removed, and this greatly reduces not only power consumption but also the number of damaged grain. Unloading from silos goes by the lower conveyor which directs the grain to the elevator to load it into the grain tank. There is a diverter valve to turn the grain stream into trucks. The conveyor delivers grain to the elevator which raises it to a required level. The valve is switched to unload, and grain is discharged into discharge jet.

Process flowchart has provisions for the internal movement of grain. This operation is used in case of additional cleaning of grain, further drying of grain, grain unloading by lots to different vehicles, disinfection of the infected batches of grain, refreshing and cooling of grain before long-term storage, and for subgrading grain at mill silos when preparing milling blends.

Elevator is used to lift grain to the desired level. Elevator scoops the grain with buckets, lifts it to the desired height and then the grain is unloaded through a connector into a grain pipe by the way of centrifugal forces [10]. Scraper chain conveyor is used to move grain horizontally. The work of chain conveyor with inset scrapers is based on moving bulk materials with the help of scrapers which are set onto the circle chain located in a closed metal box. Grain is unloaded through openings in the bottom of the box. Electrically driven diverter valves are used to switch from loading to unloading mode. There are some supporting facilities in the granary. When grain reaches the top level of the silo, a gate valve closes and grain stops to flow into the given section. Such valves help to unload grain from silo.

This type of granary can be distinguished from others by a number of features. The most important feature is the possibility to introduce automation of different settings.

3. AUTOMATED CONTROL SCHEMES

Automation functional scheme is the main design document which defines structure and automation level of operating procedures at the designed object. Operating scheme indicates main connections between separate elements of the control loop and location of automation devices. As there may appear control errors due to the length of the tank, the grain tank was nominally divided into five sections. Each section has an automation unit and can be locally controlled. Such sectioning of the main tank improves the accuracy of measurement by primary transducers, and thereby reduces the control error [11-13].

There are different schemes of automation operating procedures based on relay logic. The development of algorithms on the basis of the logic is executed with a certain sequence of relay and magnetic starters. The extension of such control circuits by adding new relays and contactors leads to a complete change in the control circuit. The complexity of remote data transfer, files setting up and remote control are just several disadvantages of the relay logic control schemes which make them non-competitive in the market.

Today many control schemes that have been traditionally working on relay-contactor logic are substituted by PLC (Programmable Logic Controller) logic. PLCs differ markedly from traditional fixed-function control devices and have a lot of advantages. They are more flexible, more reliable, have smaller sizes. They can be networked with other devices and reconfigured through Internet. They detect errors faster, consume less power, require less to change its functions and structure and are generally more cost-effective in the longer term.

PLC provides high reliability, easy replication and maintenance of control systems, speeds up installation and adjustment of equipment and allows fast updates of control algorithms (even when equipment is on). PLC allows developing of the control scheme which may at any time subject be extended while the underlying hardware remains unchanged. Remote control is conducted via different data transfer protocols, and data storage is possible at a remote workstation (PC).

While developing automated control schemes under the research, OVEN PLC-160 controller was chosen as main operating element. Figure 3 shows the complete functional scheme of the granary automation. The basic functional lines are applied to the main operating scheme. The table below shows the location of the automation devices. The main functional element is the PLC-160 controller. All start-up equipment is installed on site and does not have specified location.

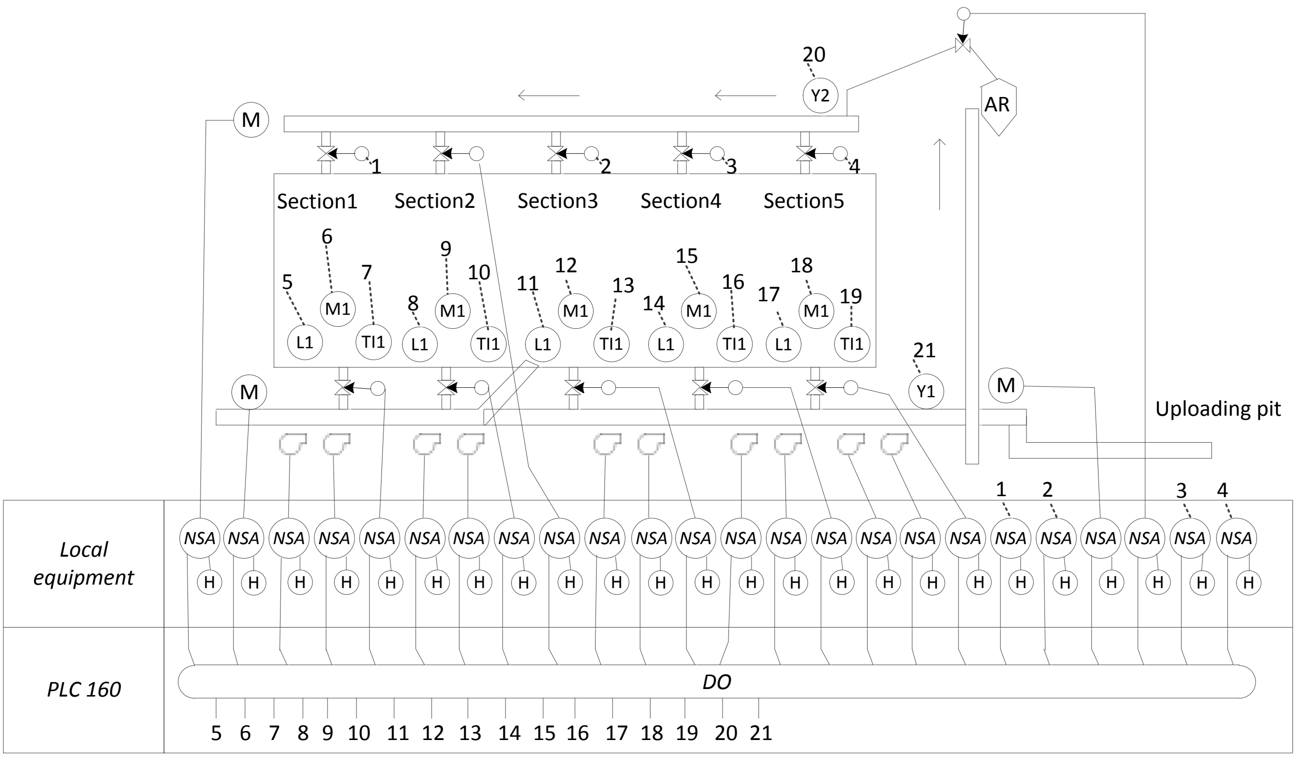

Figure 3: Functional control scheme

Each section has a level sensor, a moisture sensor and a grain temperature sensor which are denoted by letters L, M and TI correspondingly. Besides there are sensors Y1 and Y2 that control the conveyors chains to be unharmed. The output signals from the sensors go to the input of PLC-160 controller. Starting elements and gears noted as NSA are for control of operating units. The motor control is in manual (H) and automatic mode. All symbols comply with the Russian State Standard "Automation of Technological Processes" (GOST 21.404-85[14]). Manual control is conducted through installed control devices, while automatic control is performed by controller algorithm. Soft start frequency control is used to control motors. Reverse control circuits are used to control diverter valve and tank gate valves. Arrows show the possible operating flow. When loading into the silos, grain undergoes the following route: "Unloading Pit – Elevator – Diverter Valve – Top Conveyor – Silo". When unloading, the grain goes to "Silo – Bottom Conveyor – Elevator – Diverter Valve – AR-12 Unload Nozzle".

The OVEN PLC-160 controller has the following properties:

- powerful computing resources and large memory;
- digital and analog inputs/outputs;
- serial ports (RS-232, RS-485);
- Ethernet port for high-level local or world network;
- support of Modbus (RTU, ASCII), OVEN, DCON communication protocols;
- possibility to directly connect to the controller ports - this allows to connect external devices with custom protocols;
- integrated real-time clock that allows to create control systems with specific time requirements;
- built-in battery for a number of additional functions (short-term power failure support, transfer of the outputs to a safe state).

These features fully correspond to the tasks of the granary automation. In addition, the cost of this controller is less than that of foreign origin.

Loading and unloading of grain is regulated by control gate valves mounted on the casing of the grain conveyors. Depending on the level of grain in the tank, the controller generates a signal to leave the valve open or to close it. The control scheme is a closed loop. The scheme of valves automatic control is shown in figure 4.

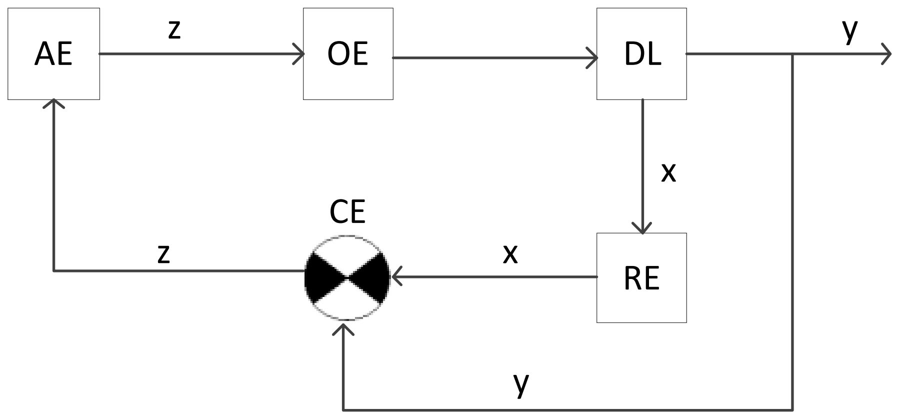

Figure 4: Valves automatic control circuit

At the output of the control algorithm there is the defined level of grain (y) which is sent to the comparing element (CE). The CE is the PLC-160 controller. The defined level x is captured by a receiving element (RE - the level sensor) and transmitted to the comparing element which compares two signals, generates the control signal z and sends it to the amplifying element (AE). The amplifying element is a contactor. At the output of the amplifying element there is a received signal Z which goes to the input of the operating element. The operating element is the valve. The signal Z closes or leaves the valve open.

Available schemes of automation and monitoring do not allow keeping track of intermediate data values. For example, relay-contactor control circuit can control only several levels of grain in the tank, and the quantity of levels depends on the number of level sensors [14-22]. The authors of the article upgraded control systems of granary operating procedures. This made possible to create more efficient control scheme with the possibility of remote control and monitoring. Figure 5 shows the structural diagram of automated control schemes (ACS) of the operating procedures.

The diagram includes three levels: field level, controller level and top level.

The field level includes grain level sensors, grain temperature sensors, grain moisture sensors, limit switches of gate valves and diverter valve and engine launch protection.

The controller level collects and processes data and sends control signals. The main part of this level is OVEN PLC-160 controller which has the control algorithm installed. The PLC-160 can conduct the granary automation without extension modules. If the capacity of the controller must be increased in connection with the increased production then the extension modules may be used. The controller level forms the middle level of ACS. This level acts as a brain of the system or a local level (domain).

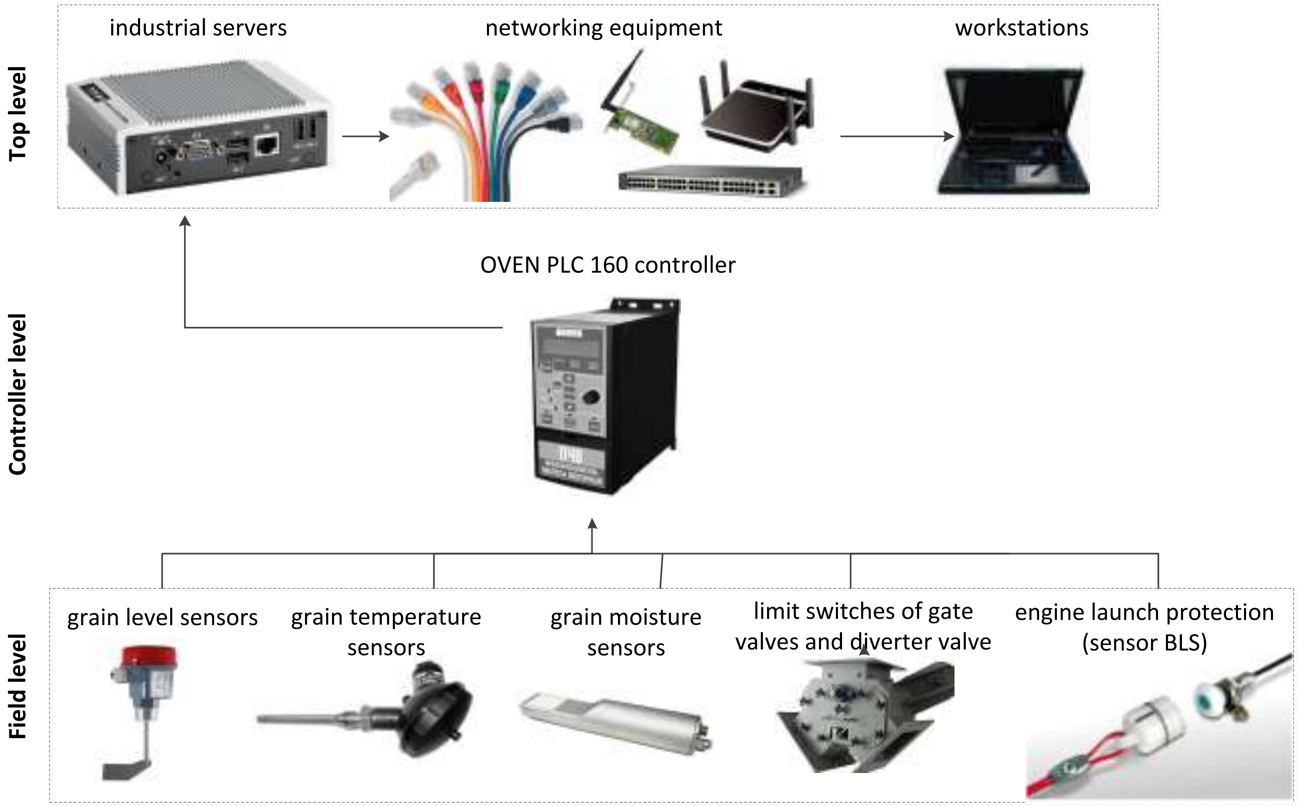

Figure 5: Structural diagram of automated control schemes of the operating procedures

Measuring sensors (Sensor 1 – Sensor N) collect and preprocess signals which later are sent to the inputs of the PLC. Depending on the signal type here are two types of inputs: discrete signals and analog signals. The lower level of ACS is formed on the basis of the sensors. This level is responsible for the data collection.

The top level of the control system is HMI (human-machine interface). This level is for collection and storage of information. The main element of this level is a man, and this is the main level in all the control hierarchy.

Safety interlocks are included to prevent non-routine operations on the basis of existing equipment. Frequency inverter controls electric drives, limits starting currents and prevents damage to the equipment. The control scheme includes blocking of the conveyor start if it is under load in order to exclude braking of the conveyor. It also gives alarm signal to an operator in case of damage to the conveyor belt. Damage to the conveyor is controlled by induction sensors; under-load start is controlled by pressure sensors.

The top level is the level of industrial server, network equipment, the level of an operator and dispatch stations. This level is for SCADA system which allows remote control and monitoring of operating procedures in granary.

Figure 6 shows complete scheme of data transmission and remote control of operating procedures.

The connection between devices is either wired or wireless. Data signals from sensors go to the PLC. Here work the control algorithms for upper and lower gate valves, control of diverter valve, control of loading, unloading and mixing of grain. All data from the PLC are systematically saved on the server. In case of emergency the PLC can be remote controlled through the server or workstation that has access to the server.

Special attention is paid to monitoring of the operating procedures. In addition, the server receives data from operational and security camcorders. Operational camcorders are inside the granary; the data transferred from these cameras allow monitoring of grain condition in the granary in real time. Security camcorders traditionally allow monitoring of the territory of the granary.

Unfortunately, this system cannot use intelligent sensors and Internet technologies so far as the concrete structure of the granary will block the signal. The main data transfer protocol between intelligent system elements is the widely used

Modbus RTU Protocol. Ethernet exchange goes at a local level and does not transfer data to the top level. Wireless technology is used to transmit the data to this level.

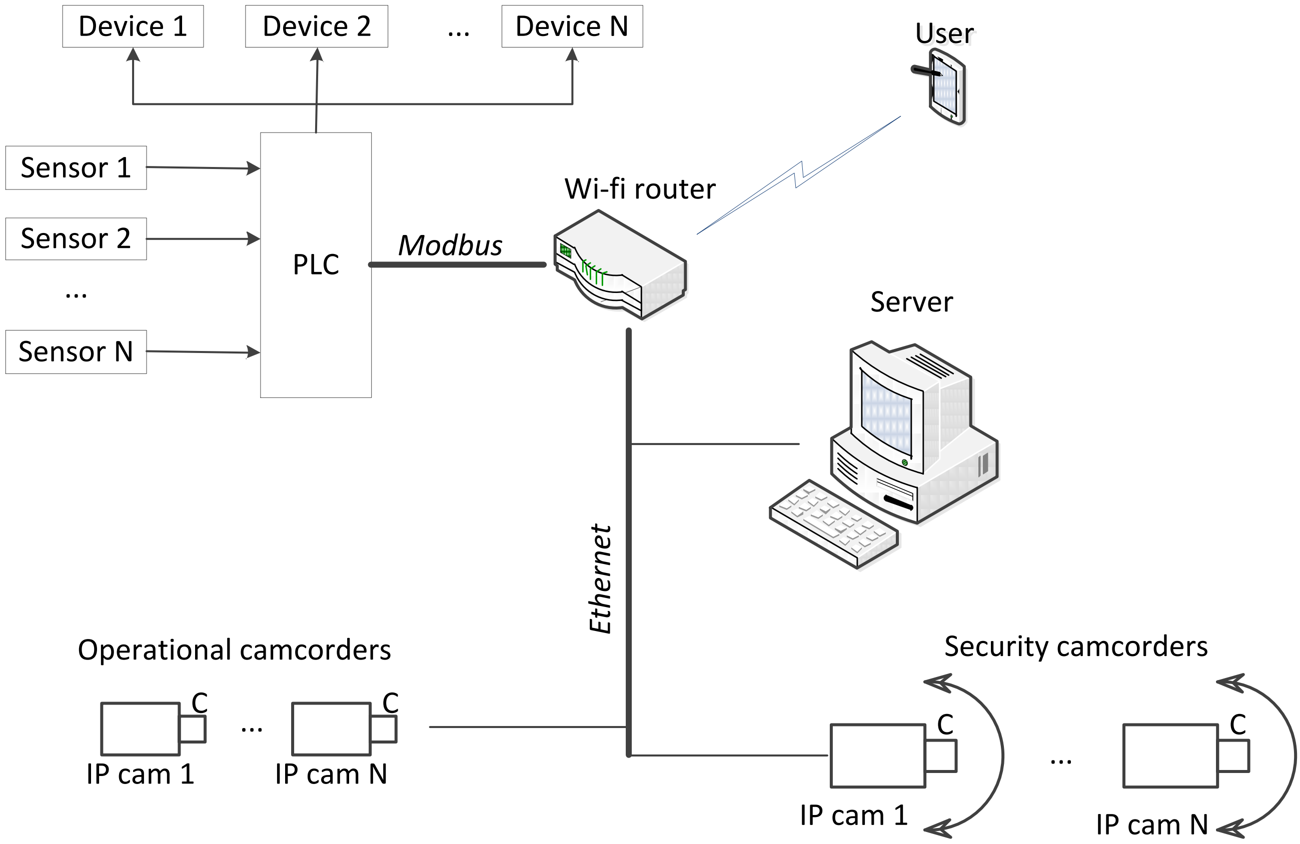

Figure 6: Logic scheme of data transfer and remote control

Hardware support goes through the OVEN PM01 units. Communication with the OPC server of Modbus OPC/DDE type is used for remote control of the granary. This server allows the communication with the hardware of different manufacturers working through the Modbus RTU Protocol. The OPC server allows data transfer up to 9000 baud/s when number of input signals is up to 300. This means that the system will work without waiting for the system response. The OPC server allows controlling of several separate granaries from one place.

The main advantage of the described control schemes is cheaper hardware provided by OVEN company. Many control schemes currently are being implemented on the basis of controllers from Siemens, Schneider Electric, Legrand etc. Taking into consideration the current dollar and euro exchange rate, the schemes carried out by the given controllers are not a "budget choice". As a result many eventual customers refuse automation. One of the main ideas of this research work is finding the equipment that would be excellent value for money.

This work was carried out in the Northern Kazakhstan so this facility shall not be used in seismic activity areas.

4. CONCLUSION

Introduction of new and specifically digital technologies is necessary for higher-quality grain storage. The system of remote control and monitoring will allow more efficient work of the staff. Automated control allows eliminating of deterioration in the quality of stored grain.

As a result of this research we developed control scheme, selected system hardware and designed control lines to the sensors that ensure non-stop and effective operation of a granary. The given control schemes provide granary monitoring and control. These schemes allow to track the movement of each specific lot of grain, conduct a continuous counting and timely analysis of grain parameters, strictly control grain acceptance procedures and reduce the shortages.

Automation of granary was performed on the basis of OVEN PLC-160 controller. Special attention was given to the flexibility of the system. As the result this system can be integrated into an existing control scheme, even if it is the relay-contactor logic.

We considered the issue of top-level control and monitoring through wireless technologies. The proposed hardware is the most suitable in the ratio of cost to the provided functional capacity.

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