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Real Time Supervisory Control Application for a Natural Gas Compressor Station

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Abstract

The supervisory control application works in real time in the control room. The proposed architecture takes into account the main human machine interface requirements and deals with the complex process of transmission gas network, more exactly with compressor station process. Operator interface is provided by three computers running applications developed with FactoryTalk View software. Application allows controlling valves, pumps, loops, monitoring of the plant by optical and audible warnings when abnormal situations occur, recording of important process parameters. The paper discusses the functions and implementation of proposed architecture as applicable to the industrial case of a Romanian compressor station.

Key words: *real time scheduling, compressor station; gas networks, PLC, ModBus.*

Controlled Process

The natural gas demand worldwide is in a continuous growth. More natural gas was consumed in the United States during 2011 than in any previous year — approximately 24.4 trillion cubic feet (TCF). This compares with 19.6 TCF in 1991, 21.8 TCF in 1971, and 6.8 TCF in 1951 [1]. In Europe, gas crisis from 2011 lead to finding solutions for storage and transportation of natural gas. So in the last decade, there has been a trend toward increasing pipeline-operating pressures. Higher pressure means the ability to transmit larger volumes of gas through a given size of pipeline, lower transmission losses due to friction, and the capability to transmit gas over long distances without requiring or even reducing additional compressor stations [5]. Transmission gas networks are composed by compressor stations and pipelines which transmit gas at high pressure from a gas source to demand points. In gas transmission, two basic types of compressors are used: reciprocating and centrifugal compressors [5]. Reciprocating compressors are usually driven by either electric motors or gas engines, whereas centrifugal compressors use gas turbines or electric motors as drivers. The cost of fuel consumed by compressor stations is the most significant operation cost of transmission pipelines; they consume about 2 % of the natural gas running through them [6]. That is why the control of compressor station is very important, and its operation must minimize fuel gas consumption of the compressor whereas demands of consumers are satisfied and the compressors are operated in a cost-efficiently way [2, 5, 7]. There is also a trend in integrated design of control structure and process for compression stations [1, 3, 4].

The proposed application monitors all the important parameters from a Romanian compressor station and also gives the possibility of emergency shutdown (ESD). This application offers the

safe operation of compressor station, the possibility of establishing the output of the plant using the throughput manipulator and real time monitoring and supervisory control of compressor station.

The Proposed Architecture for Real Time Supervisory Control Application – Case Study

The proposed application serves the station from plantwide to specific sections and utilities of the gas compression station. From plantwide control overview, the compressor station operating point is the result of the pressure conditions imposed by the system. The pressure imposed by the system may be dependent on the flow.

Input-output representation

The main goal of the compressor station is the compressor output to be controlled to match the system demand. This can be done by finding the throughput manipulator for the plant. An input output overview of the plant is presented in Figure 1.

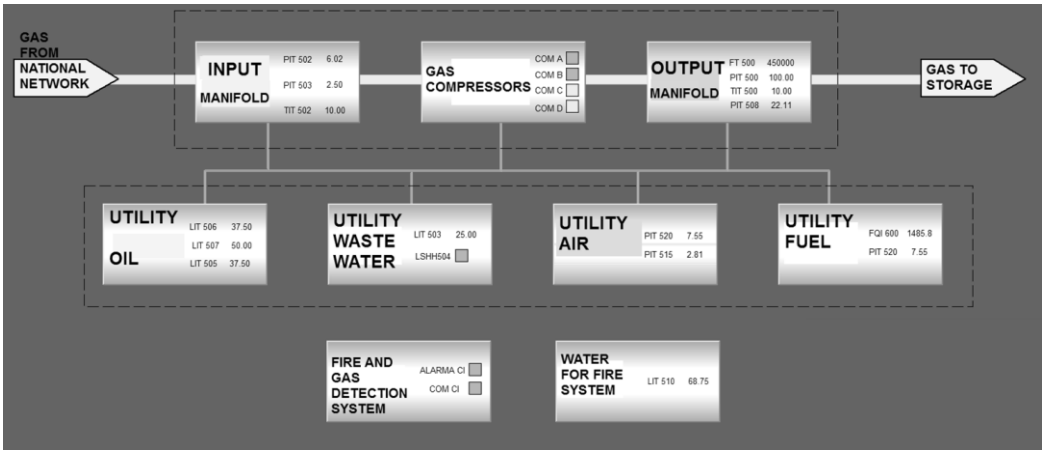


Fig. 1. Input-output representation of the compressor station.

The compressor station from Figure 1 compresses the gas to be stored for winter higher demands. At this level only the main parameters are presented in real time: the pressures and temperature for inlet manifold, the working status of the 4 compressors, the pressures, temperature, flowrate for outlet manifold, the level in oil tanks, the levels on waste water tank, the pressures for technical air, the flowrate and pressure of utility fuel, the main alarms form Fire and detection gas system, the level in water tank for fire system. The proposed application provides a journal of events, alarms and operator interventions.

The inlet manifold

The inlet manifold comprises all necessary preparing for gas compressor. The section contains two large collectors and two scrubbers. The most important parameter from plantwide control perspective is the pressure from national gas network which is maintained at necessary level according to the demands. The pressure from national gas network is monitored and if the pressure is bellow a threshold the shutdown valve (SDV) closes and triggers the protection system of compressors. The products of scrubbers are the gas for compressors, the gas used as fuel and the waste water that goes to waste water system (fig. 2, [6]).

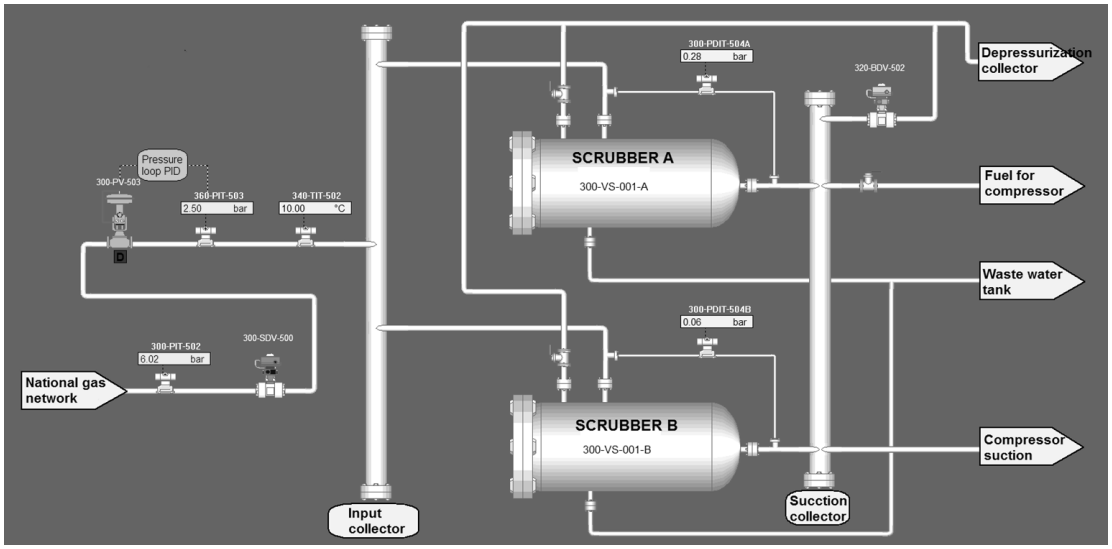


Fig. 2. Inlet manifold with main control loops and monitored parameters [6].

The compressors system

The next system refers to compressors functionality and protection. The protection system takes into account the alarms from depressurization collector enabling the emergency shutdown of the plant (ESD). Also the system works with blowdown valves (BDV) and SDV. In the gas collector system is available the main product of the compressor station used to go to storage room (here is measured by three sensors – flowrate, temperature and pressure). The compressor station can be designed to extract gas from storage for intervals with growing gas demands.

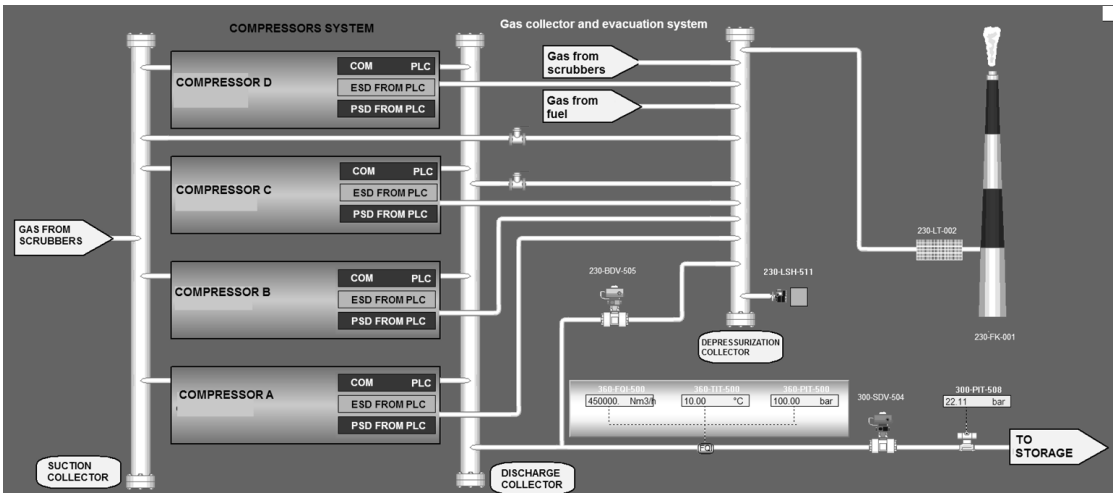


Fig. 3. The compressors, collector and evacuation system.

The waste water system

The waste water from the station is collected in the waste water tank and must be carefully monitored due to environmental constraints. The prevention fire system need a functional hydrant network, assured by a pump station and a water tank. The storage water tank must be filled to a minimum level in order to ensure a properly work of the pump station.

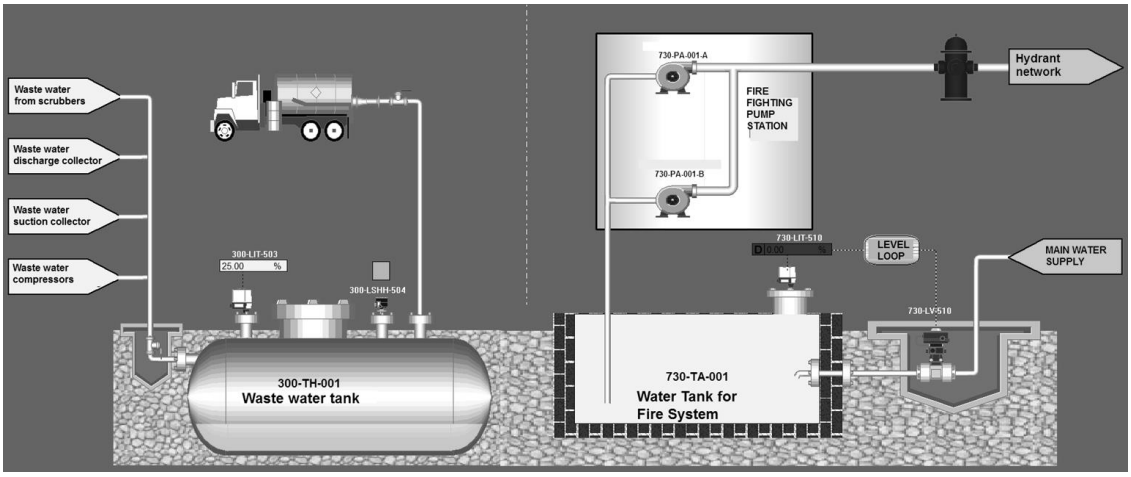


Fig. 4. Waste water and fire fighting systems.

The fuel and technical air systems

The fuel supply system (fig. 5) contains two pressure control loops vital to the system. These pressure control loops ensure the necessary fuel for compressors. The malfunctioning of these loop compromise the compressor station output.

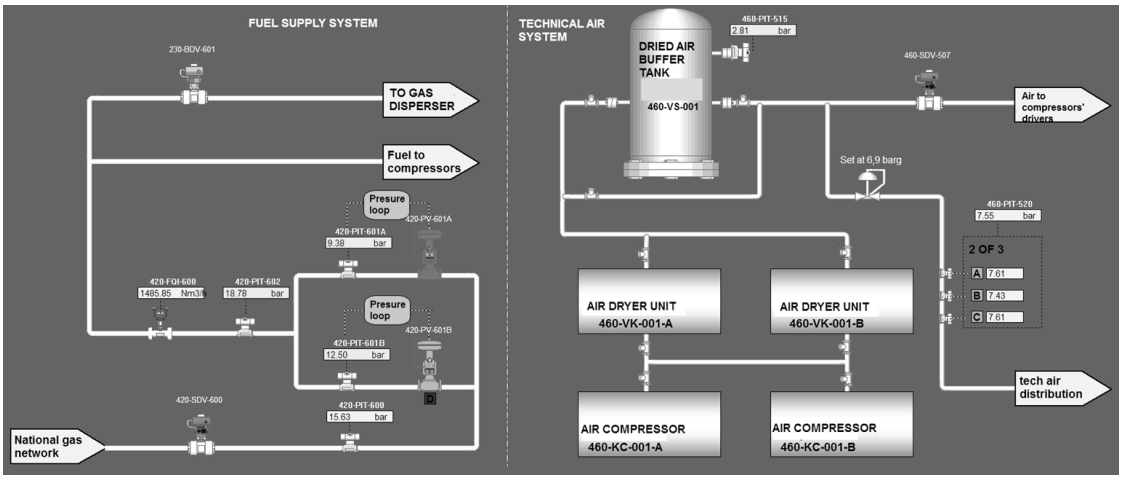


Fig. 5. Fuel and technical air systems.

Another vital system is technical air utility system. The system provides air to compressors' drivers and to all hydraulic commands within compressor station. Here is adopted the redundancy solution TMR (Triple Modular Redundancy with 2 from 3 voting system).

The application also provides reports and trends of the monitored parameters. The gas flowrate measuring system from Figure 3 (from collector to storage) is presented is presented in figure 6 and its trend is visible in Figure 7. Actually there is visible here only the outlet pressure and the temperature measuring point.

Fig. 6. Gas flowrate metering from a Romanian compressor station.

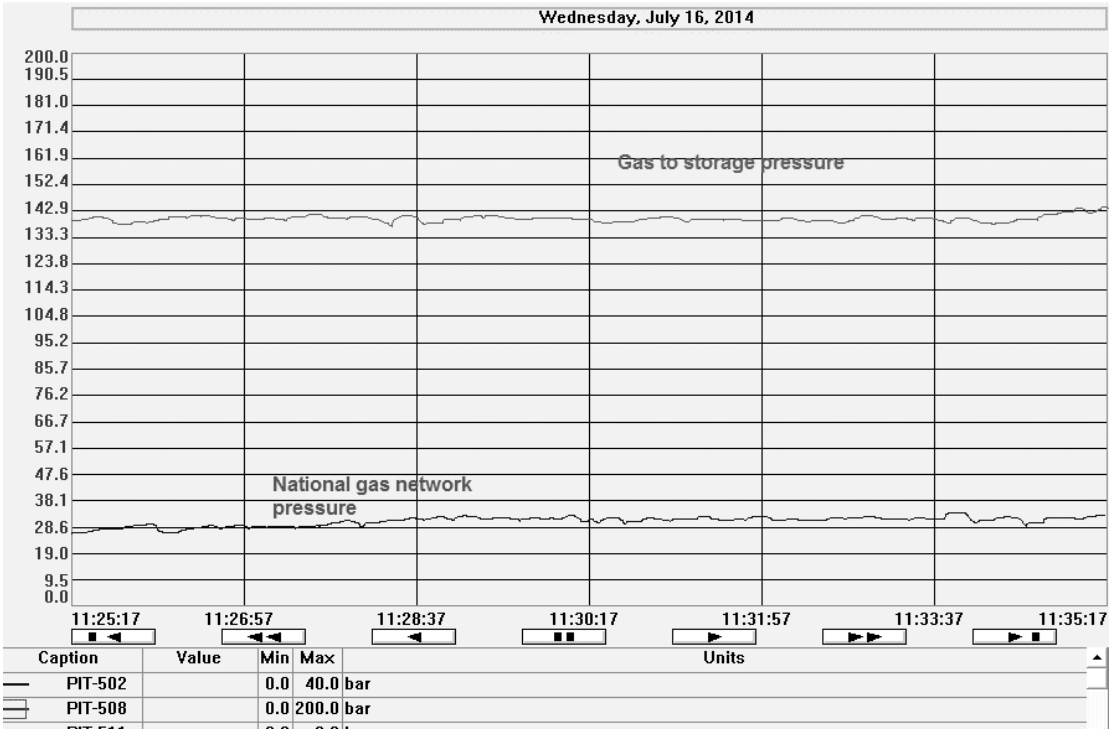


Fig. 7. Real time trends on pressure reports.

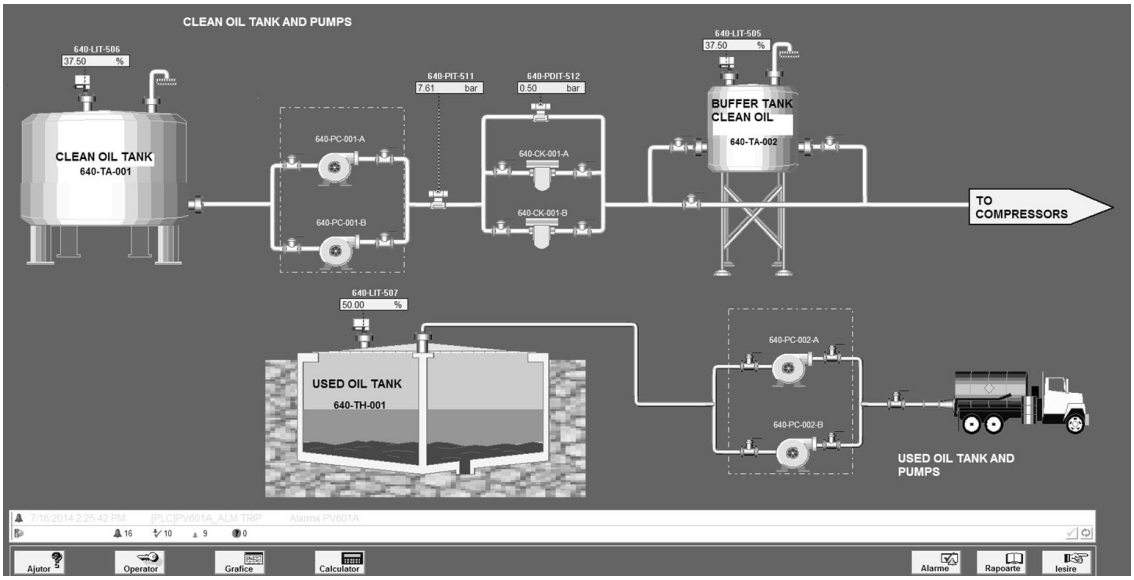


Fig. 8. Utility system - oil.

The Oil System and Fire, Smoke and Gas System

The oil system (fig. 8) has two main parts: the clean oil and the used oil systems. Any shortage in supplying this utility is transmitted to the supervisory control system that can shutdown the entire plant. The environmental constraints must be also fulfilled.

The application takes into account the alarms from a Fire, Smoke and Gas System that works separately from automation system.

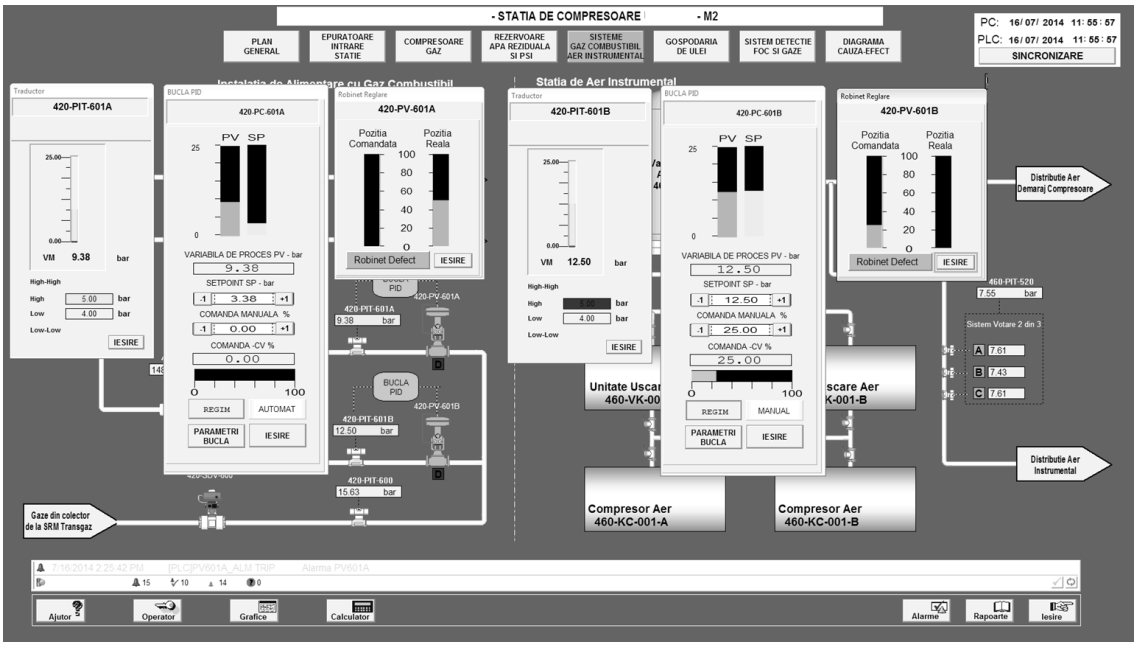
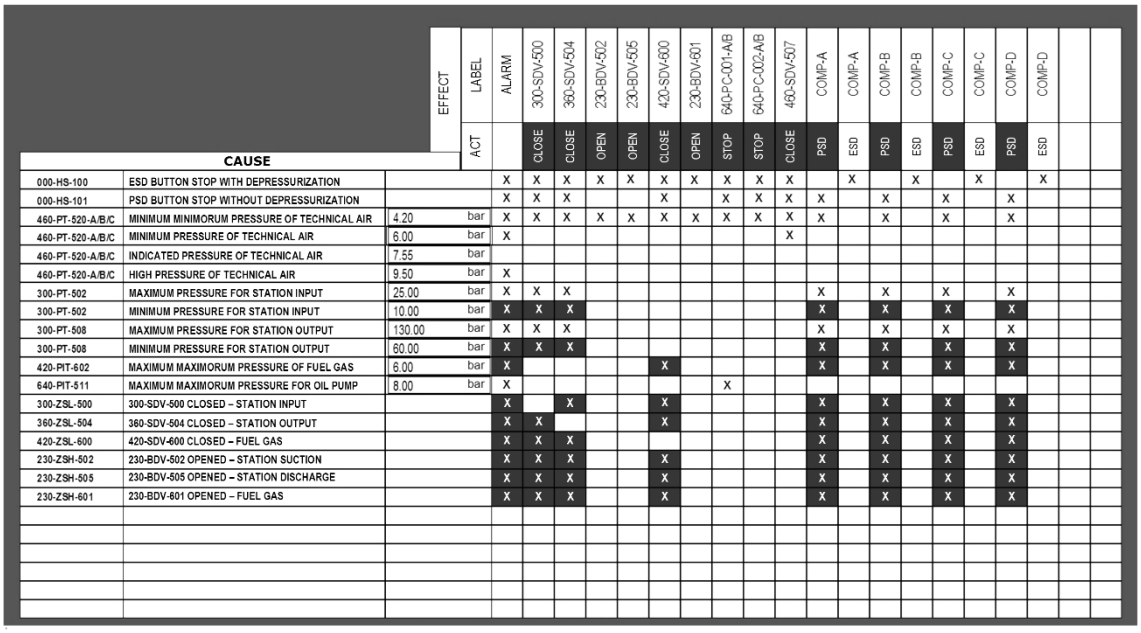


Fig. 9. Human machine interface for proposed application.

The proposed application allows the operator to change parameters according to his credentials (fig. 9). Usually the operator can monitor the parameters associated to the subsystems of compressor station, but also can intervene with command mainly to blowdown and shutdown

valves. In the case of control loops, the operator can operate the control system and every intervention is written in operator interventions journal.



CAUSE				EFFECT	LABEL	ALARM	300-SDV-500	360-SDV-504	230-BDV-502	230-BDV-505	420-SDV-600	230-BDV-601	640-P-C-01-A/B	640-P-C-02-A/B	460-SDV-507	COMP-A	COMP-A	COMP-B	COMP-B	COMP-C	COMP-C	COMP-D	COMP-D		
					ACT		CLOSE	CLOSE	OPEN	OPEN	CLOSE	OPEN	STOP	STOP	CLOSE	PSD	ESD	PSD	ESD	PSD	ESD	PSD	ESD		
000-HS-100	ESD BUTTON STOP WITH DEPRESSURIZATION					X	X	X	X	X	X	X	X	X	X		X		X		X		X		
000-HS-101	PSD BUTTON STOP WITHOUT DEPRESSURIZATION					X	X	X			X		X	X	X	X		X		X		X			
460-PT-520-A/B/C	MINIMUM MINIMORUM PRESSURE OF TECHNICAL AIR	4.20	bar			X	X	X	X	X	X	X	X	X	X	X		X		X		X			
460-PT-520-A/B/C	MINIMUM PRESSURE OF TECHNICAL AIR	6.00	bar			X									X										
460-PT-520-A/B/C	INDICATED PRESSURE OF TECHNICAL AIR	7.55	bar																						
460-PT-520-A/B/C	HIGH PRESSURE OF TECHNICAL AIR	9.50	bar			X																			
300-PT-502	MAXIMUM PRESSURE FOR STATION INPUT	25.00	bar			X	X	X								X		X		X		X			
300-PT-502	MINIMUM PRESSURE FOR STATION INPUT	10.00	bar			X	X	X								X		X		X		X			
300-PT-508	MAXIMUM PRESSURE FOR STATION OUTPUT	130.00	bar			X	X	X								X		X		X		X			
300-PT-508	MINIMUM PRESSURE FOR STATION OUTPUT	60.00	bar			X	X	X								X		X		X		X			
420-PIT-602	MAXIMUM MAXIMORUM PRESSURE OF FUEL GAS	6.00	bar			X					X					X		X		X		X			
640-PIT-511	MAXIMUM MAXIMORUM PRESSURE FOR OIL PUMP	8.00	bar			X							X												
300-ZSL-500	300-SDV-500 CLOSED – STATION INPUT					X		X			X					X		X		X		X			
360-ZSL-504	360-SDV-504 CLOSED – STATION OUTPUT					X	X				X					X		X		X		X			
420-ZSL-600	420-SDV-600 CLOSED – FUEL GAS					X	X	X								X		X		X		X			
230-ZSH-502	230-BDV-502 OPENED – STATION SUCTION					X	X	X			X					X		X		X		X			
230-ZSH-505	230-BDV-505 OPENED – STATION DISCHARGE					X	X	X			X					X		X		X		X			
230-ZSH-601	230-BDV-601 OPENED – FUEL GAS					X	X	X			X					X		X		X		X			

Fig. 10. Input-output conditions.

After summarizing all the above conditions for plant operation the result is cause – effect diagram from figure 10. The important actions that can be taken are shutting down the SDVs, opening up the BDVs, shutting down the plant (compressors A, B, C and D - PSD) and emergency shutting down the compressors (ESD).

The data acquisition is made with a sampling time of 10 ms. The reports are available for the critical parameters of the compressor station from the real time database where the parameters depending on their change dynamics are updated with the necessary frequency.

Conclusions

The objective of the paper is to create a human machine interface that monitor and record process parameters, to control the valves and the oil pumps, to alarm on abnormal situations, to manage communication system. SDV and BDV provide compressor station emergency stop when dangerous situations occurs. Also it was implemented a communication system in which important parameters are taken from gas compressors, flow computers. Data transmissions between the four compressors control unit and control room use Modbus RTU protocol and the connection is achieved through a redundant fiber optic network.

All equipments located in hazardous areas have explosion protection and ATEX certification according designer specifications.

The control cabinets are equipped with components from well-known producers: programmable controllers ControlLogix from Rockwell Automation, signal conditioners from Pepperl and Fuchs. Programmable controller software was developed with RSLogix 5000.

Operator interface is provided by three computers running applications developed with FactoryTalk View software. The stations monitors display synoptic diagrams of the technological installations. In all screens it can watch real time values of process parameters (pressure, temperature, level and flow), functional status of control valves (closed, open and ajar), oil pumps (available, unavailable, turned on/off) and the status of fire, gas and smoke

detectors. Application allows controlling valves, pumps, loops, monitoring of the plant by optical and audible warnings when abnormal situations occur, recording of important process parameters.

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Aplicaţie pentru supravegherea şi conducerea în timp real a unei staţii de comprimare a gazelor naturale

Rezumat

Aplicaţia de supraveghere şi conducere lucrează în timp real, în camera de control. Arhitectura propusă ia în considerare principalele cerințe impuse interfețelor om-mașină și se ocupă cu procesul complex de transport al gazelor în rețea, mai exact cu procesul asociat stației de comprimare. Interfața operator este asigurată de trei calculatoare care rulează aplicații dezvoltate cu software-ul FactoryTalk View. Aplicația permite comanda robinetelor de reglare, pompelor, buclelor de reglare, monitorizarea centralei de avertizare optică și sonoră, atunci când apar situații anormale, înregistrarea parametrilor importanţi din proces. Lucrarea discută funcțiile și punerea în aplicare a arhitecturii propuse, pentru cazul industrial al unei staţii de comprimare româneşti.