INTELLIGENT SOFTWARE APPLICATION FOR CONTROL AND MONITORING OF DEGASSING PROCESS

Vali Sirb, *Lecturer, University of Petrosani*
Angela Egri, *Assoc. Prof., University of Petrosani*
Emil Sergiu Andras, *Eng. Mine Paroseni*

ABSTRACT: *This paper presents the knowledge-based intelligent software application for control and monitoring of vitally important industrial degassing process from degassing stations. For this purpose we created friendly user interface. This was designed to allow communication between the user and the computer system through a window using images, messages, menus and commands. The data acquired from the process we monitored and driven over with data acquisition boards, Data Acquisition Card (DAQ) and displayed using virtual instruments were created using LabVIEW graphical programming language. The knowledge base is made up by the assembly of all the specialised knowledge introduced by the knowledge expert. Rules base contains basic information necessary to solve the problem (initial facts) and also inferred facts deduced after triggering of the reasoning performed in the inference engine. The state of each element is determined by a „if-then" rule. All rules have been implemented using C ++ and were loaded into the controller through the controller interface.*

KEYWORDS: *knowledge base, intelligent control, monitoring, interface , rule-based systems, degassing station*

1. INTRODUCTION

The high complexity of the degassing stations and the necessity to monitor the parameters referring to the : cooling water pressure with water gauge ,depression Gas Extraction , the discharge gas pressure ,concentration of methane ,presence of water in gas filters due to the condensation process , current absorbed from mains electric vacuum pump ,methane gas pump temperature ,the maximum hot water, minimum of hot water ,minimum of hot water ,the presence of methane gas pumps hall ,air temperature, detection of methane gas ignition, the maximum water separator , minimum level of water in the separator, impose intelligent monitoring well mathematical based solutions and concretized by the conceiving of the knowledge-based intelligent systems [1] for control and monitoring for a real industrial degassing stations. The intelligent system developed and implemented requires the creation of the following components (Fig. 1): knowledge base, data acquisition module, interface, inference engine, and user interface.

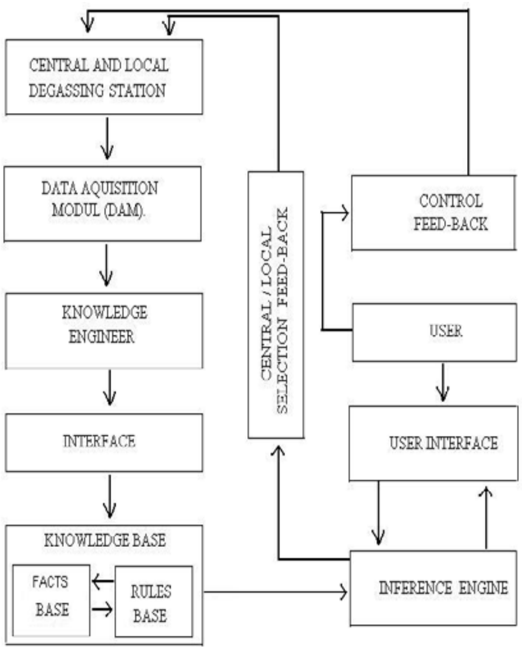


Fig. 1 Architecture of intelligent system

2. USER INTERFACE

The user interface is designed to allow communication between the user and the computer system through a window using images, messages, menus and commands [2]. The application software developed and implemented (Fig. 2) Intelligent Control System main window opens the display of which allows access to menus: Process And Installations (Proc. And Inst.) , Acquisition Data Module (D.A.Q. M), Facts Base, Rules Base, Monitoring And Control (C and M) with submenus: control panel (Fig. 3), synoptic signals (Fig. 4) and Layout of the equipment (Fig. 5).

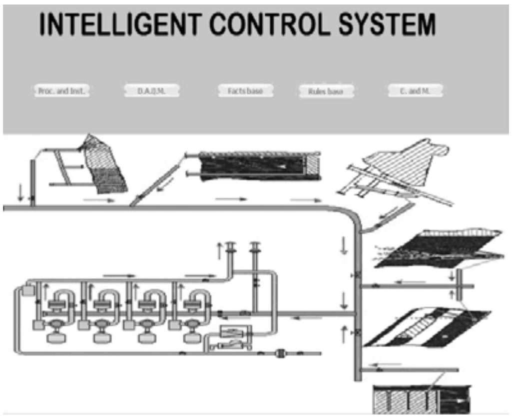


Fig. 2 Intelligent Control System main window

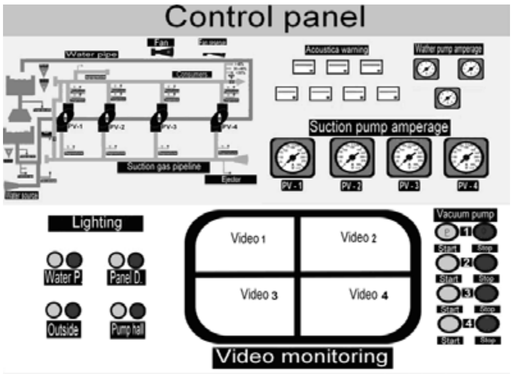


Fig. 3 Control panel

Monitor and adjust parameters were acquired from sensors in the system, they are: cooling water pressure with water gauge (Pa); depression Gas Extraction (D); the discharge gas pressure (P); concentration of methane (CH_4 analyzer using); presence of water in gas filters due to the condensation process (FAP); current absorbed from mains electric vacuum pump (APV); methane gas pump temperature (Tg); the maximum hot water (NMC); minimum of hot water (Nmc1); minimum of hot water (Nar); the presence of methane gas pumps hall (MCA); air temperature (Ta); detection of methane gas ignition (Ap); the maximum water separator (Nam); minimum level of water in the separator (NMA). Virtual measuring instruments were created in Adobe After Effects environment and were converted file type "flash". Moving elements of virtual instrumentation (Fig. 6) have been simulated using Adobe Photoshop and PhotoFiltre.

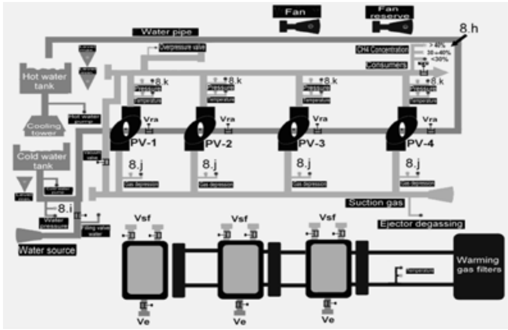


Fig. 4 Synoptic signals

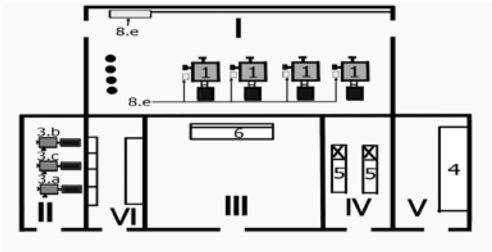


Fig. 5 Layaut of the equipment

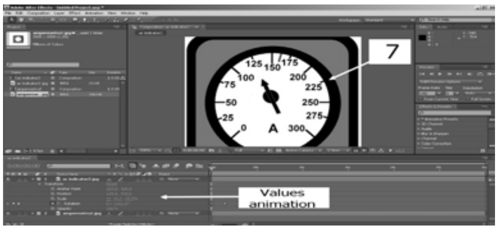


Fig. 6 Virtual instrumentation

3. PROCESSES AND INSTALLATIONS

The intelligent system that was developed and implemented monitors and controls the processes from degassing stations. The first process is centralized and is composed of a central degassing station and a local caption of methane and the second is performed locally using the central station which becomes operational only when the central degassing station fails. The central degassing station facility is located at least 20 meters from any adjacent building and is equipped with devices to capture atmospheric over voltages. Given the engine – pump group's placement in the same room the electric motors that drive the vacuum pumps are made in protection class Exd, IP 64.

Driving the vacuum pumps using belts is prohibited. The degassing facility is equipped with 2 backup pumps and immediate coupling possibilities. Each month a running degassing pump will be switched with a backup pump. The backup pump will undergo maintenance and repairs to ensure that they will function properly. The main degassing station (Fig.7) is made of: 4 vacuum pumps (Fig.7) of which 1 is running and 3 are backup having the following characteristics:a flow of gas 20-28 ($m^3 \cdot \min$), depressurization of gas 92-395 (mmHg), pressure of gas 50-90 (mmHg); 4 drive motors (Fig.7) with the following characteristics: electric power ($75 \cdot 10^3 w$), speed engine 735 ($rot \cdot \min^{-1}$),voltage 380 (V); three water pumps(Fig.4) as follows: warm water pump, cold water pump, backup pump. The water pumps have the following characteristics: flow of water 400-650 ($l \cdot \min^{-1}$), pressure of water 2-4 (bar)speed engine 1445 ($rot \cdot \min^{-1}$). The water pump drive motors have the following characteristics: electric power ($7{,}5 \cdot 10^3 w$), voltage 380 (V):Oil pump (Fig.4); Fan (Fig.4); Control panel (Fig.3; Control and measurement (Fig.4) devices: gas analyzer with concentration indication and continuous recording of drawn,flow meter that continuously indicates and records the amount of sucked gas, vacuum meter to control the depressurization in the drain pipe, manometer to control the pressure in the pipe, thermometers to control gas temperature in the suction and discharge pipe and cooling water control, gas analyzer for automatically controlling the concentration of methane in the chamber where the vacuum station is mounted and in the control room, located on the highest point where methane can form. Protection and safety devices (Fig.7): a flame-retardant device on the exhaust pipe prevent the transmission of an outside explosion in

case the gas mixture is ignited; a flame-retardant device on the inlet of the pipe that sucks the gas, installed before the installation of suction station to prevent the transmission of any explosions in the underground station and vice versa; Flame-retardant device on the supply pipeline of potential consumers, to prevent the transmission of a possible explosion of consumer degassing plant and vice versa; impurities retention filter; water separator; separation valves; automatic control device for maintaining constant depression in the suction pipe; Automatic cut-signaling device and suction facility when the concentration of methane in the suction pipe. Methane gas flows through a system of pipes (Fig. 8) where it is driven by (depression) with the help of vacuum pumps P (Fig. 8), and inside the pump cooling water is sprayed. Before entering the pump, the gas is passed through filters F (Fig. 8) to remove dust particles. Removal of cooling water from the gas is achieved in the vacuum pump separator(Fig. 8) and final separator SF (Fig. 8) of the plant.

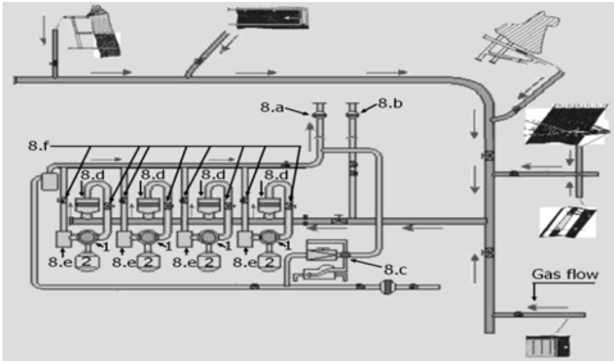


Fig. 7 Central degassing station and gas flow

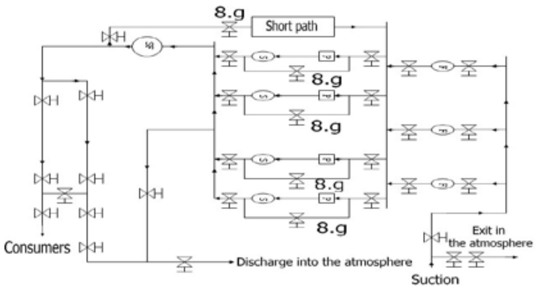


Fig. 8 Pipe system diagram

The suction power of the vacuum pump P is adjusted with the help of the installations short circuit valve. After filtration and cooling the gas is directed to consumers. The building of the central degassing facility is located at least 20 m from any adjacent building and is equipped with devices to capture atmospheric over-voltages (lightning) and is divided into six rooms (Fig.5): l Vacuum pump chamber; ll Water pump chamber; lll Control and monitoring chamber; lV Fan chamber; V Server chamber; Vl Energy distribution chamber. Local gas capture is achieved through a degassing ejector when the central degassing station has stopped because of damage (fig 9).

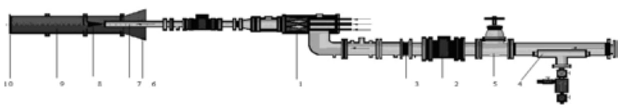
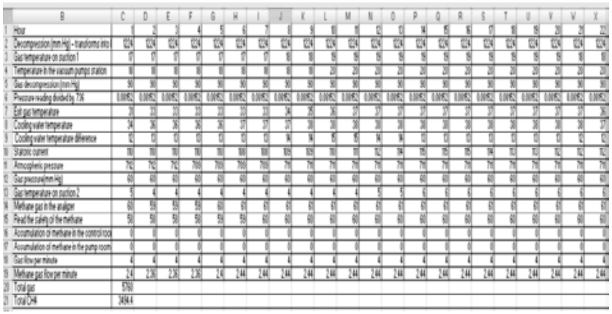


Fig. 9 Local degassing station

1 Degassing ejector; 2 Flame stopping device;3 Royal - Duth device; 4 Water – detritus – gas separator ; 5Gate valve; 6 Section for increasing the air flow in the dilution chamber; 7 Repression section; 8 Gas deflector; 9 Gas dilution chamber; 10 Wire mesh for airflow uniformity.

4. DATA ACQUISITION MODULE

The Data Acquisition Module periodically receives data from connected sensors and sends them to the monitoring system via the knowledge base management system. In order to process the data acquired [4] from the process we monitored and driven over with data acquisition boards, Data Acquisition Card (DAQ) and displayed using virtual instruments were created using LabVIEW graphical programming language. Signals provided by sensors on the degassing station are analog so it is necessary to convert them into digital signals. For this purpose we used analog-digital converters, the acquired data can be represented in several ways depending on the encoding of data: binary, Gray code or two's complement code. Measurement results were stored in a table (Fig 10), and after with their were generated graphs of variation of parameters (fig.11 and fig.12).



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
2	Decompression (mm Hg) - transforms into	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024
3	Gas temperature on suction 1	17	17	17	17	17	17	17	18	18	19	19	19	19	19	19	19	19	19	19	19	18	18
4	Temperature in the vacuum pumps station	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	20	20	20	20	20	20	20
5	Gas decompression (mm Hg)	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
6	Pressure reading divided by 736	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Exit gas temperature	31	33	33	33	33	33	33	34	35	36	37	37	37	37	37	37	37	37	37	37	37	36
8	Cooling water temperature	34	36	36	36	36	37	37	37	38	38	38	38	38	38	38	38	38	38	38	38	38	37
9	Cooling water temperature difference	12	13	13	13	13	13	13	14	14	15	15	14	14	13	13	13	13	13	13	13	12	12
10	Statoric current	110	110	110	110	110	108	108	109	109	110	111	112	114	115	115	115	114	112	112	112	112	112
11	Atmospheric pressure	712	712	712	709	709	709	709	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711
12	Gas pressure (mm Hg)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
13	Gas temperature on suction 2	5	4	4	4	4	4	4	4	4	4	4	5	5	6	6	6	6	6	6	6	6	6
14	Methane gas in the analyzer	60	59	59	59	60	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
15	Read the safety of the methane	58	58	58	58	59	59	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
16	Accumulation of methane in the control roo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Accumulation of methane in the pump room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Gas flow per minute	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
19	Methane gas flow per minute	2.4	2.36	2.36	2.36	2.4	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
20	Total gas	5760																					
21	Total CH4	3494.4																					

Fig. 10 Measurement results

Multi-purpose interface for monitoring, reading and control of acquired data was designed using the LabVIEW programming environment (Fig. 13). The signal is taken using the MyInPort subVI then is multiplied by 5(reference voltage) and divided by the 256 (number of 8-bit read data after that it is read by two indicators one numeric and one of type char.

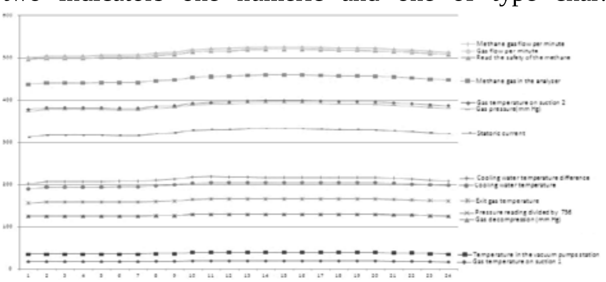


Fig. 11 Diagram of parameters

5. THE KNOWLEDGE BASE

The knowledge base is made up by the assembly of all the specialized knowledge introduced by the knowledge expert [1]. The knowledge stored here are mainly the descriptions of the objects and the relations between them. The knowledge base is part of the cognitive system, knowledge being memorized in a special organized space. The access to the knowledge base of the intelligent system is restricted for security reasons and is made by a username and a password. So, we avoid unauthorized users' access to the knowledge base which can affect the data integrity.The knowledge base contains two modules: facts base and rules base.

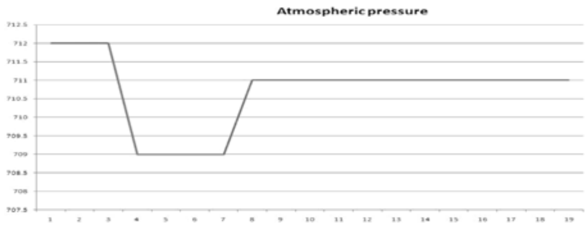


Fig. 12 Diagram of atmospheric pressure

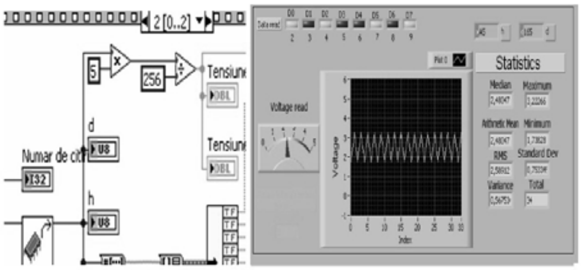


Fig.13 Interface and signal conversion

FACTS BASE

The facts base comprises the initial facts and the intermediate results produced along the deduction procedure. The facts are represented [3] using the conventional knowledge representation and the adequate mathematical formalism. The facts (fig 2) is part of the knowledge base and consists of all facts that describe the events taking place both in the central facility and the local degassing station. The events allowed in the system are given by rules of Technical Safety and Health at Work and safe operation of the plant and equipment. Starting the installation is allowed only if the degassing pipes contain (Fig. 4) methane concentration of 30%, at normal atmospheric pressure and cooling water pressure (Pa) at least 2 bar. This concentration prevents ignition of methane gas, but allows safety starting the installation. If the CH_4 sensors sense a concentration greater than 30% of gas, there is a danger of accidental initiation, so these sensors do not allow the installation to start. The facts describe these events: Starting the degassing ejector (fig.9) for loading the facility with methane gas to a safe concentration (min. 30% CH_4), stopping the ejector when the methane detection sensors detect the required concentration. The concentration value of CH_4 and the start of the synoptic ejector is indicated (Fig.4) ; Starting the cold water pump required for natural gas cooling during operation when water pressure is at least 2 bars and normal operation is at a maximum pressure of 6 bar, pressure that doesn't overload the cooling station. The water pressure value and water pump start is indicated synoptically (fig.4); Start the vacuum pump if the gas concentration and water pressure reached predetermined value. Start vacuum pump is indicated synoptic (fig.4); Starting the degassing station safely and begin degassing. They are marked synoptic (fig.4); operation of all equipment in normal working conditions. They are marked synoptic (fig.4); Stopping central plant in case of damage when an acoustic signal is emitted and starting the local plant, signaled to the control panel (fig. 3).

6. RULES BASE

Rules base contains basic information necessary to solve the problem (initial facts) and also inferred facts deduced after triggering of the reasoning performed in the inference engine. The inference engine or interpreter is the core of an intelligent system because it uses the knowledge base to build dynamic reasoning through the selection of trigger able rules based on their order of concatenation. For this it is necessary to provide an initial state for the facts base from which we can select trigger able rules, this is the filtering operation. The filtering operation is a selection of rules to be filtered, taking into consideration, initially, a subset of rules, and then selecting the rules applicable from this subset. The selection operation performed before filtering is called restriction. Then, the rules that apply are subject to a control strategy through the selection operation. All these operations are performed automatically by the inference engine that will execute the chosen rules. The state of each element is determined by a „if-then" rule and listed below:

Rule 1: If the water pressure Pa(0) in the cold water installation doesn't exceed 2 bar then the priming valve Va(1) of the cold water pump will open and the Par pump will restart.

Rule 2: If the water pressure Pa (1) of cold water facility exceeds the threshold of 2 bar, the system allows the electric coupling PV of the vacuum pump (1).

Rule 3: If the concentration of methane in facility passes the 30% threshold CH_4> 30% (1), the ejector decoupling occurs Rj (0) and the vacuum pump PV starts (1).

Rule 4: If the concentration of methane in facility has crossed the threshold of 40% CH_4> 40% (1) will signal the green synoptic Lv (1) and audible alarms disable Ac (0) of the plant.

Rule 5: If the concentration of methane in facility falls below 40% CH_4 <40% (1) the monitoring interface will signal synoptic Lg yellow (1), alarm sound of the plant is turned on Ac (0).

Rule 6: If the concentration of methane in facility falls below 30% CH_4 <30% (1), then the monitoring interface will signal red synoptic LR (1) meaning that the plant will be disengaged automatically, The vacuum pump Pv is decoupled (0) and the ejector Rj is started (1).

Rule 7: If gas depression (mmHg) is higher than 180 mmHg D> 180 (1) and gas pressure (mmHg) is lower than 10 mmHg P <10 (1), the pressure valve will close Vp (1) $1\cdot10^{-1}$rot. Rule 8: If gas depression (mmHg) is higher than 180 mmHg D> 180 (1) and gas pressure(mmHg) is higher 90 mmHg P> 90 (1), the gas shorting valve opens D (1) $1\cdot10^{-1}$rot.

Rule 9: If the water level in the gas filters increases due to condensation, it will open the water exhaust valves Ve (1) after separating the water sections from the extraction circuit by closing partial separation valves USF (1) of the extraction circuits - discharge.

Rule 10: If the current drawn from the network by starting vacuum pump motor absorbs a current greater than the nominal current for 5 seconds Apv> 5 (1), the electrical system will disconnect PV (0) will close the cooling water valve of the pump, it will open the drain valve in the pump Vea (1) and will close the valve on the underground suction pipe Vta (1).

Rule 11: If the gas temperature in the vacuum pump rises above 180oC Tg> 1800 (1), the valve opens cooling water pump VRA (1) $1\cdot4^{-1}$rot.

Rule 12: If the current drawn from the grid by vacuum pump motor during operation is greater than 160A Apv > 160 (1), then the cooling valve of the vacuum pump closes VRA (1) $1\cdot6^{-1}$ rot.

Rule 13: If the pressure in the cold water pump rises above 6 bar Pa.> 6 (1), the shorting valve between the suction and discharge water pumps Vpar opens (1) $1\cdot6^{-1}$rot.

Rule 14: If the water level in the hot water basin reaches the maximum level Nmc (1), then the maximum level is signaled synoptically on the monitoring interface Lmc (1) and hot water pump will start Pac (1) to push the water to the cooling tower.

Rule 15: If the water level in the hot water basin reaches a set minimum level Nmc1 (1), then the minimum level will be signaled synoptically on the monitoring interface Lmc1 (1) and hot water pump will stop Pac (0).

<u>Rule 16:</u> If the pressure in the cold water pump falls to 2 bar Pa = 2 (1), the shorting valve between the suction and discharge water pumps closes Vpar (1) $1 \cdot 6^{-1}$ rot.

<u>Rule 17:</u> If the pressure in the cold water pump falls below 2 bar Pa <2 (1), the vacuum pump will stop PV (0).

<u>Rule 18:</u> If methane collectors detect methane in the pump chamber at a concentration greater than 1.8% methane CH_4 CMH> 1.8% (1), the vacuum pump will stop PV (0) and the ventilation fans Vla (1) and dispersion of methane will start.

<u>Rule 19:</u> If the water level in the cold water pool drops below a set lower limit Nar (1), the water supply valve opens Vam (1) to complete.

<u>Rule 20:</u> If the air temperature drops below freezing Ta<0°, then will start the “If” filter heating system starts (1).

<u>Rule 21:</u> If methane gas lights Ap (1) due to external factors (electrostatic fields, lightning), it will decouple the degassing station PV (0)._All rules have been implemented using C ++ and were loaded into the controller through the controller interface.

Next we present how to implement the R2 rule (Fig. 14).

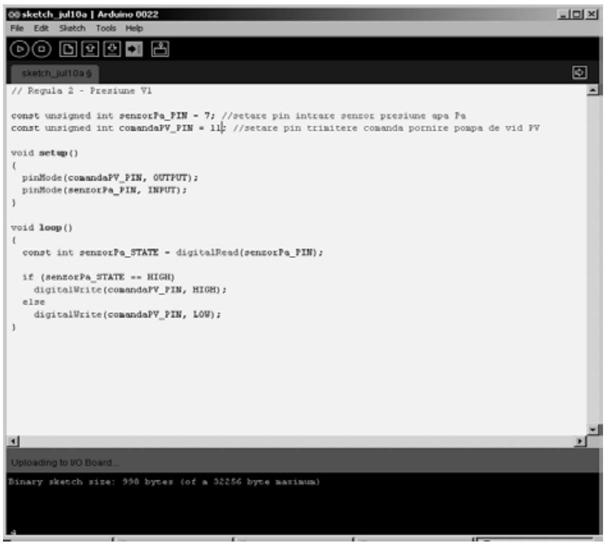


Fig. 14 R2 rule implementation

<u>// Rule 2</u>

```
const unsigned int senzorPa_PIN = 7;
 //set water pressure sensor Pa input pin
const unsigned int comandaPV_PIN = 13;
 //setare vacuum pump Pv command pin
void setup()
{
pinMode(comandaPV_PIN, OUTPUT);
  pinMode(senzorPa_PIN, INPUT);
}
void loop()
{
  const int senzorPa_STATE =
digitalRead(senzorPa_PIN);
  if (senzorPa_STATE == 1)
   digitalWrite(comandaPV_PIN, 1);
  else
  digitalWrite(comandaPV_PIN, 0);
```

7. CONCLUSIONS

This intelligent control software application resolve with high fidelity the control of vitally important industrial degassing process from degassing stations referring to the parameters: cooling water pressure with water gauge, depression gas extraction , the discharge gas pressure ,concentration of methane, presence of water in gas filters due to the condensation process, current absorbed from mains electric vacuum pump ,methane gas pump temperature ,the maximum hot water, minimum of hot water ,minimum of hot water ,the presence of methane gas pumps hall ,air temperature, detection of methane gas ignition, the maximum water separator , minimum level of water in the separator.

Runnig quickly and ofer very good control and monitoring solutions.

The software application can be extended to a larger area, more than one degassing stations what we want to do in the future.

8. REFERENCES

[1]. Alexandru, A.; (2002). *Expert systems. Concepts and aplication* , Publishing Matrix Rom, ISBN 973-685-226-1, Bucharest, Romania.

[2]. Egri, A, ; Sirb, V. ; Patrascoiu, N. ; Tomus, A. ; (2011). *Intelligent control and monitoring of drinking water distribution system.*Annals of DAAAM for 2011 & ISI Proceedings ,ISSN 1726-9769, ISBN 978-3-901509-83-4.

[3]. Egri, A.; (2002). *Artificial intelligence and robotic*, Focus Publishing, ISBN 973 -8367 - 48 – 4, Petrosani, Romania.

[4]. Patrascoiu, N, ; Tomus, A. ; Egri, A, ; Sirb, V. ; (2011). *Creating Hardware-in-the-Loop System Using Virtual Instrumentation.* 12th International Carpathian Control Conference- ICCC 2011. ISBN 978-1-61284-359-9