ALGORITHM FOR INDUSTRIAL MONITORING AND CONTROL IN PUMPS FOR GAS PRODUCTION WELLS

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ABSTRACT

This document presents the design and implementation of an algorithm for industrial control in gas pumps used in gas extraction, using the Modbus industrial protocol, as well as its configuration within a satellite network. The design is intended for the end-user to have the ability to exercise continuous control over gas production wells that are several kilometers from the control and operations center.

KEYWORDS: *Gas Pump, Industrial Control, Modbus, Satellite Telemetry, Scada*

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1. INTRODUCTION

The gas production process fulfills parameters and functions that depend largely on human labor, both to monitor quality standards, and to control the level of gas production. To fulfill these defined functions, operators must be in constant monitoring of the main production wells.

The technical operating personnel in charge of attending to production levels and supervising the state of the equipment in charge of gas extraction, repeatedly do not have a reliable tool for decision making in their processes and the quality of communications from the wells located several kilometers from the monitoring center is not efficient, causing trips to the points of interest and carrying out control of the valves, actuators and sensors from the wellhead, affecting response times to their clients and over-costs not calculated for the project in issues related to transportation and consumables. With the help of an effective monitoring tool and the use of satellite hardware for communication, the control and supervision of the wells can be done more easily and efficiently, reducing response times and greatly reducing the high costs of travel [1]-[3].

That is why designing and implementing the satellite software and hardware tool can help solve communication problems, significantly improving the control of the wells from the monitoring center. For the development of the tool, we will take into account the problems, needs and advantages offered by this system concerning the constant loss of communication and cost-time benefits with operators in the field [4]-[6].

2. DESIGN OF THE MONITORING TOOL

2.1. Analysis of the communication ports of the existing equipment

To begin with the design and implementation of the communications system for the telemetry service, it is essential to know the communication ports and hardware status of the equipment that in the field obtains data (PLC, RTU) from the main sensors and actuators used in gas control from the wellhead. The system consists of a Vmonitor reference

RTU, XARTU/1 [7], which is the intelligent device of the good control system, responsible for receiving the information obtained by the sensors and process it to be displayed by the human-machine interface and operating software, Figure 1 shows the schematic diagram of the RTU board.

NOTE:

THE DIGITAL I/O TERMINALS (TB2) MAY BE SOFTWARE CONFIGURED TWO WAYS.
FIRST, AS DIGITAL OUTPUTS, THEY PRESENT THE RELAY STATUS SIGNALS FOR K1 (PORT 1.1), K2 (PORT 1.2), & K3 (PORT 1.3).
SECONDLY, AS DIGITAL INPUTS, THEY MAY BE USED TO EXTERNALLY ENERGIZE THE THREE COILS.
IN EITHER CASE, LOW (APPROX. 1.7V) = ENERGIZED.
THERE IS A 100K PULL-UP ON THE INPUT.

Figure 2: Interrogation of Modbus records

With the interrogation, the following list of signals is obtained, to which a label (TAG), description and Modbus address number are assigned, to facilitate their search within the registers, which is evidenced in Table 1.

Table 1: Modbus register list

TAG	Description	Modbus Register
GHP	Gas Pressure Before Adjustment	40337/Reading only
THP	Tubing Pressure	40345/Reading only
CHP	Casing Pressure	40349/Reading only
GAP	Gas Pressure After Adjustment	40339/Reading only
GDP	Gas Differential Pressure	40341/Reading only
ZT	Instantaneous Gas Flow	40347/Reading only
QT	Instantaneous Gas Flow	40351/Reading only
FQS	Flow setpoint	40357/Reading Writing
ZS	Valve setpoint	40359/Reading Writing

2.3. Development of the Control system application

In the previous sections, the necessary information for the configuration of the telemetry service was collected, identifying that the system uses the Modbus protocol of multiple registers in the Holding values.

Table 2 shows a brief description of the data types used in the Modbus protocol [8], [9]. The RTU configuration is composed of Holding Registers, which are used as a 16-bit variable for each of the Modbus addresses used.

Table 2: Types of data used in Modbus

Value Type	Description	Type-Variable
Coils (Discreet Outputs)	Individual Bits	Read-write
Inputs (Discrete inputs)	Individual Bits	Reading only
Input Registers	16-bit words	Reading only
Holding Registers	16-bit words	Read-write

As the system handles large data exceeding the value 65535 in a string of integers, within the same block or record

position, it is not possible to display it using a 16-bit variable, so the Modbus protocol provides a simple solution [10], [11] handling function code types for each type of data, this to differentiate between an operation and another using single-byte numbers, this number tells the slave what function or operation has to do.

Table 3 shows the different types of functions handled by the Modbus protocol, for this particular case should be made a further development to implement the reading and writing of Modbus registers using function 16. Since in the Modbus frame obtained from the interrogation is evident that the RTU responds to this type of function.

Table 3: Modbus function types for holding register values

Value Type	Description	Type-Variable
03 (03 Hex)	Reading of the holdings	Read what value one or more Holding Registers have stored
06 (06 Hex)	Deed of a holding	Write a value between 0 65535 in a single holding
16 (10 Hex)	Writing of multiple holding	Write a value between 0 65535 in several holdings

The application is developed under JavaScript and consists of Web services that perform the respective operation of reading, writing and saving Modbus records in the database of the main server.

To understand the operation of web services and integration of the satellite network used, Figure 3 shows the topology implemented in the development of the project in the field.

Figure 3: Scada Network Topology

As presented in the topology of Scada Network implemented [12]-[14] there is a Web service that allows interaction between the satellite network and the server with the Web application, in this service, was developed the module for the integration of the telemetry system in gas wells.

Figure 4 presents a block diagram about the operation of the above-described topology, detailing different services that interact within the satellite topology and the monitoring of the records in real-time of the equipment located in the field.

Figure 4: Block diagram topology of the Scada network

For the development of the algorithm used in the wellhead telemetry system in gas pumps, it consists of three specific functions:

- Modbus Interrogation: Allows reading of logs, complying with the standard Modbus/RTU communication protocol.
- Storage of records in the database
- Modbus writing: Allows to write to the Modbus registers, complying with the standard of the Modbus/RTU communication protocol.

With the new development, the implementation of the algorithm is used within the topology as a Web service [15], [16] that interacts with the satellite Gateway and the main server, as can be seen in Figure 5.

For the register writing function used in this project, only will be allowed the use of function 16 of the Modbus protocol observed in Table 3 because as specified in the information survey, the system responds Modbus register of multiple variables.

The development of the Web application takes into account each of the above-mentioned web services for the development of the application. The system consists of a Web application that allows interaction between the user and the data obtained from the logic controllers of the equipment in the field (Drive, Sensor, PLC, RTU).

Figure 5: Block diagram of the topology of the Scada network with the software application developed

The development logic is composed of an object-like module that is called by the Web application to execute the first validation in the system, and is to ask if the user is sending a request either to write or read the Modbus 16 function, which corresponds to gas wells, this module is called in the development as Function 16MOB.

The system will now give an error response in case the Modbus frame characteristics are not met, the register does not exist or there is a loss of connection between the Gateway or unit satellite.

If the system complies with the protocol validation the application will call one of the Modbus modules either to write or read the registers in a given time. For the Modbus register reading module with function 16, it is allowed depending on the project to make a poll to the slave with the time defined for the monitoring of particular equipment.

Also in these modules, there are error responses either by a bad configuration of the Modbus address in the message frame or lost connection with the satellite gateway or the main server of the application.

If the Modbus request in function 16 receives a read or write a response, the system will return the values of the obtained frame to function 16MOD, which will make the respective connection with the WEB application using communication protocols [17] API in English Application Programming Interface, which is a set of routines that provides access to functions of a given software.

With the response of records to the Web application, the system proceeds to make their respective storage of records in the main database, where different treatments are made to the information to be presented on the Web to the end-user. In the following graph, it is detailed with clarity the flow chart implemented in the development of the monitoring and control application in the gas pumps.

The development integrates the use of Java libraries to perform the communication Master-Slave and Master-Slave is integrated within each module of reading and writing that integrates the development of gas pump monitoring.

To understand a little bit the functioning of the libraries, they comply with the characteristics of the Modbus protocol, where it is activated to function 16 of multiple registers to establish communication between the master and the slave. Where its main function is to send communication frames in Modbus protocol to have a response from the registers either by request of writing or reading.

Figure 6 details the use of the library and the communication process between slave and master.

Figure 6: Communication Flowchart Slave Master

2.4. Telemetry System Implementation

The telemetry system installed, has a self-sustaining power system, implementing solar panels and batteries to supply the load of the satellite antenna, Figure 7 shows the electrical diagram of the system implemented.

Figure 7: Electrical diagram of the Satellite Telemetry System

For the installation of the electrical system is proposed the list of devices that make up the electrical diagram in Figure 7 presented in Table 4.

Table 4: List of electrical elements power system

Quantity	Description
1	Outdoor Cabinet - Nema 4x
1	Lead-acid battery, 12 v / 84 ah
1	Solar panel 12 v / 90 w
1	Sunsaver ss-10l-24 Voltage Controller
1	IDP 680 Satellite Unit

After the power system has been mounted, the satellite unit is installed together with the solar panel [18] on its respective support. Finally, the entire telemetry system is left installed in the field (Figure 8).

Figure 8: Solar Panel and Satellite Unit Installation Photography

With the satellite system installed in the field, the communication configuration is done by specifying the type of serial connection, Modbus protocol and identification of slave devices, in this case, the RTU board [19].

3. RESULTS OF CONTROL TESTS WEB APPLICATION

Connectivity test and visualization of registers from the satellite gateway is performed, evidencing data reading of Modbus registers previously configured and analyzed during the project (Figure 9).

With the validation of reading records, integration tests with the Web application are carried out, and results are obtained from the records obtained from the RTU. Also, write tests are performed to the records in the field and satisfactory response is obtained.

Name	R 40337	R 40339	R 40341	R 40343	Phrase	R 40345	R 40347	R 40349	R 40351
PLC-GAS2	0	0	0	0					
PLC-GAS2	0	0	0	0					
PLC-GAS2	0	0	0	0					
PLC-GAS2	0	0	0	0					
PLC-GAS2	0	0	0	0					
PLC-GAS2	1868580116	1843872883	1243628217	26755793					
PLC-GAS						3787343136	3582214772	905985952	4092413339
PLC-GAS2	1532511508	3977987184	719340219	26755793					
PLC-GAS						3787343136	3582214772	905985952	916931996
PLC-GAS2	1532511508	2634105968	3932177081	26755793					
PLC-GAS						3787343136	4120134260	905985952	916931996
PLC-GAS2	1532511508	2634105968	3932177081	26755793					
PLC-GAS						3787343136	4120134260	905985952	916931996
PLC-GAS2	1532511508	2634105968	2325758650	26755793					
PLC-GAS						3787343136	3582214772	905985952	2971223451

Figure 9: Reading records from the Satellite Gateway

In the following image is shown the result of the variables seen from the web system, with the help of the development to allow the integration of multiple registers with the Modbus protocol.

Figure 10: Read and Write log display Web Application

4. CONCLUSIONS

During the analysis and collection of information about the characteristics of communication and Modbus protocol, it was evident that the current application through which the control and monitoring were provided should implement a new module for communication with multiple registers through the Modbus protocol, this is fundamental since it is a key technical feature to define the alienation and viability of the project and its development.

Functionality tests are performed, where it was possible to appreciate the correct integration of the developed application and its storage of records of multiple variables as indicated by the Modbus communication protocol.

It was evident that with the new implementation carried out with the satellite unit, the operating costs and consumables of the operators in the field were reduced by more than 70%, since with the control system the communication falls were reduced, facilitating that the operators did not have to make the recurrent trips to the production well, which notably impacts the operating costs.

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