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Dairbayeva S.A.

International Information Technologies University,
Republic of Kazakhstan, Almaty
E-mail: sabina.dairbaeva@mail.ru

Automatic Process Control System of Main Pipeline

The article is devoted to the Information system development that allows to automate the pumping process and change the thermal characteristics of pipeline. In winter, influence of temperature leads to significantly increasing of hydraulic friction, that can lead to breaking and oil pipeline "congelation". The author offers the Information system based on SCADA system with using multifunctional MasterScada platform, which makes possible to perform the oil pumping process simulation and also collection, archiving and displaying of data. It was elaborated structural diagram of data collection that allows to reorganize big data during oil pumping process and monitor the main parameters of pipeline. The functional process scheme of automation the oil transportation process considers in the article, by the example of pipeline section (206 km) between two intermediate pumping stations in the area from Beyneu to Kulsary. The developed system provides continuous working of oil pipeline that decrease energy demands of oil pumping process and workload flow of oil fluid, and also speed up the processes of identifying and troubleshooting of equipment. The advantage of developed Information system is control and automatic regulation of main pipeline parameters during changing of thermal regime. Distinctive feature of the system is that controlling of hot oil pumping process can be realized in real-time mode.
Key words: oil pumping and transportation processes, Information system (IS), Automatic Process Control System (APCS), Supervisory Control and Data Acquisition (SCADA) system, Functional process scheme.

Даирбаева С.А.

Автоматизированная Система Управления Технологическим Процессом магистрального трубопровода

Статья посвящена разработке информационной системы, позволяющая автоматизировать процесс горячей перекачки нефти при изменении температурного режима подземного трубопровода. Влияние температуры особенно сказывается в зимний период и приводит к значительному возрастанию гидравлического сопротивления, что может привести к остановке и «застыванию» нефтепровода. Автором предложена информационная система на базе SCADA систем с использованием многофункциональной платформы MasterScada, с помощью которой осуществляется симуляция процесса перекачки нефти, а также сбор, архивирование и отображение данных. Представлена структурная схема сбора данных, позволяющая упорядочить многочисленные данные в процессе перекачки нефти и проводить мониторинг основных параметров трубопровода. В статье рассмотрена функциональная схема автоматизации процесса транспортировки нефти на примере отрезка нефтепровода (206 км) между двумя промежуточно-насосными станциями в районе от Бейнеу до Кульсары. Разработанная система обеспечивает бесперебойную работу нефтепровода, что снижает энергозатраты процесса перекачки и загруженность расхода нефтяной смеси, а также ускоряет процессы выявления и устранения неполадок оборудования.

Преимуществом разработанной информационной системы является контроль и автоматическое регулирование основных параметров трубопровода при изменении температурного режима. Отличительная особенность системы, это то, что контроль и управление процессом горячей перекачки нефти может осуществляться в режиме реального времени.
Ключевые слова: процессы перекачки и транспортировки нефти, Информационная система (ИС), Автоматизированная Система Управления Технологическим Процессом (АСУ ТП), Система диспетчерского контроля и сбора данных (СКАДА), Функциональная схема процесса.

Даирбаева С.А

Магистральдық құбырының технологиялық процесстерді басқару автоматтандырылған жүйесі

Мақала жер асты құбырын температурасын өзгерту кезінде ыстық мұнайды айдау процесін автоматтандыруға мүмкіндік беретін ақпараттық жүйесін дамытуға арналған. Температурның сірі әсерісе қыста әсір етеді және әкелуі едәуір ұлғайуына гидравликалық күшейткіш әкеледі, оның тоқтауыны және мұнай құбырының қатып қалуына. Автор ұсынады акпараттық жүйе SCADA базысында, жүйесын пайдаланады көп функциональді платформаны MasterScada оның арқасында жасалады модельден процесс сорғымен айдап қотыру мұнайды, сонымен жинайды мұрағаттау және бейнебетте деректерді ұсынады. Мұнайды қайта айдау процесінде көптеген деректерді ұйымдастыру және мұнай құбырының негізгі параметрлерін бақылауға мүмкіндік беретін деректерді жинау құрылымдық сұлбасы. Мақала Құлсарыға Бейнеу ауданы екі аралық сорғы станциясының арасындағы құбыр бөлімінде (206 шақырым) мысалында мұнай тасымалдау үдерісін автоматтандыру функционалдық диаграммасын сипаттайды. Дамыған жүйесі мұнай қоспасы ағынының энергетикалық аудару процесін және кәдеге жаратуды азайтады құбырының, үздіксіз жұмысын қамтамасыз етеді, сондай-ақ аппараттық проблемаларды анықтау және жоюды тездетеді. Температурасын өзгерту кезінде дамыған ақпараттық жүйесін артықшылығы құбырының негізгі параметрлерін бақылау және автоматты бақылау болып табылады. Жүйенің ерекшелігі ыстық мұнай айдау процесін бақылау және басқару нақты уақыт жүзеге асырылуы мүмкін.
Түйінді сөздер: мұнай сорғымен айдап қотыру және тасымалдау процесстері, ақпараттық жүйе (АЖ), технологиялық процесстерді басқару автоматтандырылған жүйесі, деректерді бақылау және қадағылау жүйесы, функционалдық процесс схемасы.

1 Introduction

Oil and gas industry is one of the most important component of the economic development of any country. Consider high cost of oil recovery and production, Kazakhstan oil companies engaged by development and introduction various Information systems in this industry. For solving this task, first of all, attend to automation of oil pipeline computing parameters and thermal "hot" pumping condition processes of main pipelines [1]. The using IS in the sphere of oil pipeline execution depends on the issues which developer set up. These tasks are divided into several classes: maintenance operation, technological and protection classes. Maintenance operation is rework process of equipment and main pipeline constructions, ensuring by material and technical resources. Examples of these constructions: Pumping/Heating station (PHS) and Control station (CS). Technological class includes planning, monitoring and controlling oil delivery process. Right distributed system allows effectively manage by technological process. Processing efficiency can be increased by introducing Automatic Process Control System (APCS). Last, protection class means environment protection, safety, insurance of equipment and financial-economic sector. The development of automated information system is one of the direction of scientific-technical progress, which is used self-regulating software and mathematical methods. Those methods excuse people from receiving data and information transfer. Also decrease workload of actual operation. Information system allows to raise the workforce productivity, improve quality of process, optimize controlling, excuse people from manufactory that dangerous to health.

2 Automation of oil delivery process

Automation of technological process means realization of particular functions. First, changing technological characteristics of temperature, pressure, oil flow rate and other values. Second, automatic regulation of technological process parameters and discrete control by operational conditions of processing equipment. Here key moment is emergency shut-down system with deviation alarm. Deviation alarm suppose valve status (open/close) or equipment (device on/off). During the measurement process from sensing unit along cable, the signal sends value to controller, where it undergoes primary processing (analogue-to-digital conversion, checking for accuracy, noise filtering) [2]. After from controller digital code over network receive to Automated workstation (AWS). On the AWS operator sees the parameter values. However automatic regulation of technological parameter implies feedback. For this function the controller is also responsible. AWS operator can choices manual mode for regulation, or automatic mode. Another function of automation process is that stopcock or valve always give status notification information. This advantage allows timely find equipment deterioration. Also automation of technological process supposes emergency shut-down system. It means that if equipment break, oil delivery will be under threat. Controllers accomplish primary information gathering. This information stored as data array in main memory. Data exchange between controller and server is realized by using messages. Messages are formed by controller in cases if discrete parameter changing, timing deadline or output parameter value outside boundaries (minimum, maximum). Messages are stored in memory buffer and another special array, which contains information about current status of parameters. Control station (CS) sequentially scans data from each controller. At that time controller encapsulate messages from memory buffer and field of current status information. After packages are transmitted over the CS communication link and stored in archives database (archive data). Database and archive data is a set of tables that contain operational (current), historical and normative-reference information about the system parameters. Interface of process and its simulation can be implemented in SCADA system. When operator select particular object on the monitor, this data from operation database read to SCADA database. System has its own database for temporary store values that appear during particular time. So, automation of technological process means realization different functions from measurement process and its feedback to status notification information with emergency shut-down system. All this work perform controller, which contains memory buffer for messages. After controller send processed data to Automated workstation (AWS). For controlling and facilitation the work Control station (CS) use SCADA system, which includes two databases: for current status of parameters and for archives data [3].

3 SCADA system

Engineering of diverse systems possible on the basis of Supervisory Control and Data Acquisition (SCADA) systems. SCADA it is software package for visualization and control of technological processes. System gives a visual representation of the process and provides graphic operator interface for control and management. Also it allows to decide any issues of Automatic process control system (APCS) for oil industry. Products of SCADA very popular in world. Many companies from USA and Russia developed programmable products of system such as MasterScada, InTouch, Citect, TraceMode, Sitex, RealFlex, Genesis, FIX, Factory Link, Cimplicity etc. The choice of SCADA-system is a represent difficult task, some of programs require additional investment. However InSAT company provides an opportunity use the product in the demo version for free. Besides all this, Master Scada is leader of Russia market. Most popular oil and gas companies that use Master Scada. They are: Gazprom, Rosneft, Lukoil, Irkutskenergo, Kalinin Nuclear Power Station and others. Master Scada is a multifunctional platform that allows to design various control systems. With Master Scada program user can perform system simulation, also collecting, archiving and displaying data [4]. Technical system involve “Computer” element. It is a personal workstation that performs following functions: different equipment connection, database connection and data transfer to another computer. “Computer” can contain several elements: Object linking and embedding for Process Control Server (OPC Server), Master Link, Database connector (DB connector), controllers and input/output modules. OPC Server it is application that allows to perform handler functions for information exchange with external data sources like controllers and I/O modules. The exchange occurs by specific protocol, according to specification standard. Master Scada supports OPC Data Access (DA) and OPC Historical Data Access (HAD) standards. OPC DA grant access to interchange data in real time. OPC HAD provides the same access only to already stored data. Usually if necessary get archived data, use exactly OPC HAD Server. Both standards describe the receiving present data and interact with external devices, I/O modules and controllers. For using this servers InSAT company create MasterOPC Universal Modbus Server. The scheme of receiving data in OPC Server looks like: OPC Server using the integrated driver take data from lower level, analyze it and establish quality character with time marker, after transfer data to OPC client (Figure 1).

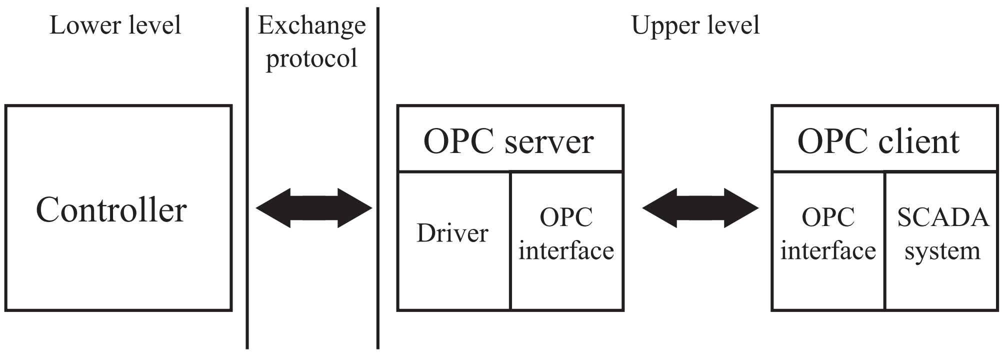

Figure 1 – Scheme of data obtaining

OPC client it is SCADA system. When Server receives the data, it test information by true/false conditions and quality character. Quality characters shows the status of OPC

Server. For instance: value is not significantly (code 0), configuration error (code 4), no connection (code 8), device error (code 12), sensor error (code 16) etc. Modbus OPC Server includes: COM, TCP/IP, PROGRAM nodes. Node is selected depending on how operator wants to receive data. It is known that each device has a unique port number. TCP / IP means that the server is running on TCP / IP protocols. PROGRAM allows work in a simulation regime. After selecting a node, need to add devices with the required settings and parameters. Variable names must be same with Master Scada parameters. All of this do for connecting OPC Server with Master Scada program, for following simulation.

4 Solution

The proposed Information system allows ordering numerous data and monitors general parameters of pipeline. As project object taken heating main oil pipeline – Uzen – Atyrau – Samara. Oil pipeline begin from Uzen minefield to Atyrau petroleum refinery, then connected with "Transneft" oil pipeline system in Samara. The length of pipeline about 1380 kilometers, on Kazakhstan territory – 1232km. Diameter of pipe is 1.020 meters and depth of laying is 1.3 m from pipe axis. For project implementation taken segment between two intermediate Pumping/Heating Stations (PHS), in the area from Beyneu to Kulsary. Distance between them is 206 km. This segment is divided into five sections. At each of sections and on the first and second PHS established actuating devices, which measure thermal characteristics of high-viscosity oil. First sensor located after 20.6 km from first PHS, other after each 41.2 km. Figure 2 shows Functional process scheme (FPS) of oil transportation automation process. There is ingress of oil through valve on Pumping/Heating station (1) takes registrations of temperature (2), pressure (3), level (4), speed of fluid movement (5), heating temperature (6). After parameters pick up, they send to the Automated workstation (AWS) (7). Then petroleum moves to Pumping/Heating station (13). However for ensure oil temperature regulation divide distance from PHS 1 to PHS 2 at equidistance. For conventions, break distance to five sections (8, 9, 10, 11, 12). On each of section takes reading from sensors: Temperature (14), Heat Capacity (15), Heat Conduction (16), Heat Exchange (17), External Temperature (18), Coat Weight (19), and Deep (20). Received parameters send to nearest AWS (23). On the Control station (CS) shows data from all AWS.

Main idea of scheme is that CS signalize any thermal changes and emergencies. In the case when temperature lowered to extremely low mar, on the CS backlight this information. After Operator, which sitting at the CS, can decide upon whether to additional oil heating. Also when any emergency situations are happen, timely intervention allows to escape high consequences. In the case when equipment fault, system shows where, on what section, with which device the accident is occurred. Besides display the message, system also provides noise. Figure 3 demonstrate emergency situation with valve in the section 1, which implemented in MasterScada program. For the present purpose, dispatcher can suspend facilities work and send out experts to crash scene.

Next, intended purpose of product is timely shows serious increasing or reduction of parameters. However, when the value already reached the point of emergency it is difficult to correct the situation. That is why necessary to compute previously minimum and maximum parameters. In addition on the table, the values are painted in certain colors, which means their evidence. Red and dark blue colors shows minimum and maximum trouble situations,

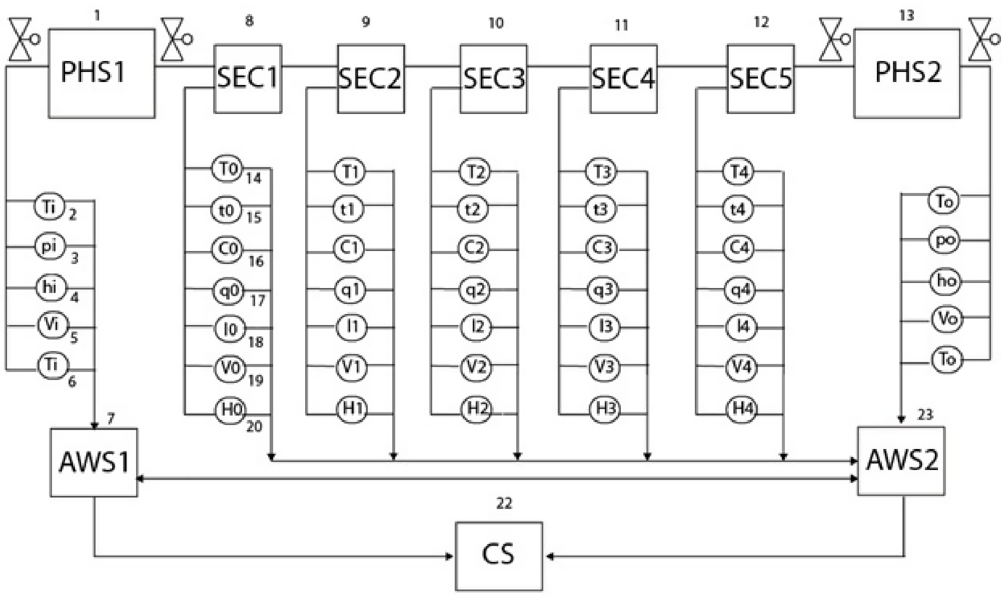

Figure 2 – Functional process scheme

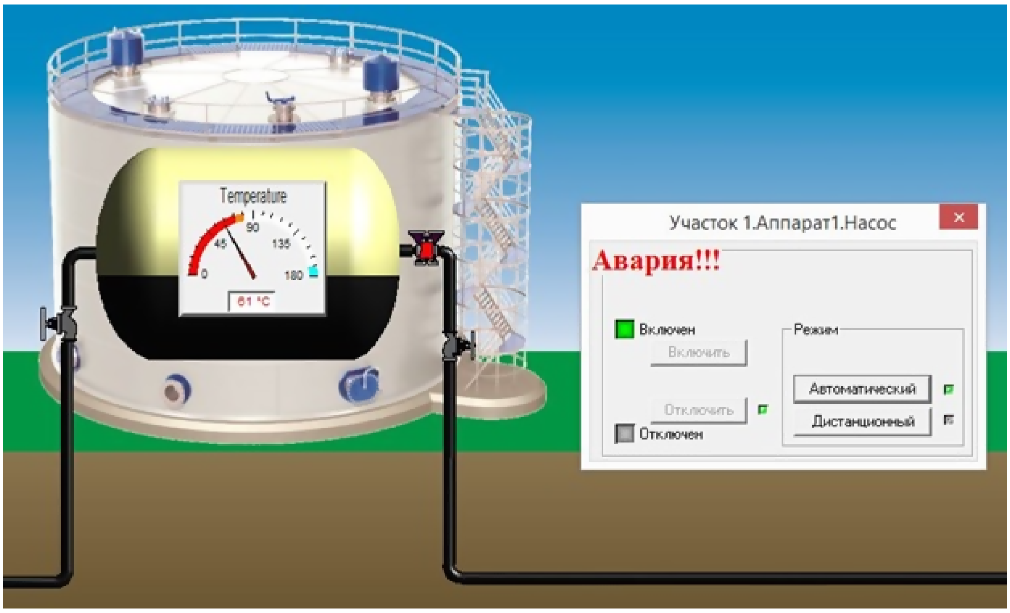

Figure 3 – Accident on Pumping/Heating station. Valve is breakdown

orange and light blue colors – minimum and maximum warning and alarm threshold. Not less useful function is trend view of particular parameter. Graphic clearly demonstrates the limits of the minimum and maximum. Program controls everything that happen and record cases when line of temperature crosses boundaries lines. Also trend displays current time (yy/mm/dd, hr/mn/sc). All of the above happens in online mode. However for full functionality was created database in Microsoft SQL Server, where storage all data from sections and stations.

Code of described procedures:

```
CREATE PROCEDURE AddValStation1 @Temperature int, @Pressure int,
@OilFlow int, @MotionSpeed int, @PreheatTemperature int AS BEGIN
Insert into station1 (Temperature, Pressure, OilFlow, MotionSpeed,
PreheatTemperature) values (@Temperature, @Pressure, @OilFlow,
@MotionSpeed, @PreheatTemperature); END

CREATE PROCEDURE AddValSection1 @HeatCapacity int, @HeatConduction
int, @HeatExchange int, @ExternalTemperature int, @CoatWeight int,
@Deep int, @Temperature int AS BEGIN Insert into section1
(HeatCapacity, HeatConduction, HeatExchange, ExternalTemperature,
CoatWeight, Deep, Temperature) values (@HeatCapacity,
@HeatConduction, @HeatExchange, @ExternalTemperature, @CoatWeight,
@Deep, @Temperature); END
```

5 Conclusion

The Information system, which is done with Master Scada platform, was developed like monitoring system with simulation mode. Functions of created product are: detection of accidents, failures in equipment; warning and emergency maximum/minimum values. It is mentioned that system failures and changes were attended with audio signal and blinked message. Significant instants create database where all received results are stored. There are several options for presenting the results: tables and graphs in simulation mode; graphs in the Trends window; tables in the database of Microsoft SQL Server. As a result, product helps to: decrease energy demands of oil pumping process, reduce workload of oil fluid flow (if necessary), speed up the processes of identifying and troubleshooting of equipment. The actuality of program is that the developed Information system allows to control oil pumping process, their general pipeline parameters and thermal regime. Finally, system works in real-time mode.

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