TANK FARM AUTOMATION

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1 INTRODUCTION

As the demand for various types of oil products and raw material of various qualities rapidly changes depending on the season, it is advantageous to optimize the production process beginning with the output of each individual component and ending with the compounding process. Such optimization makes it possible to significantly increase the economic efficiency of production, especially when up-to-date mathematical simulation methods are used. A high level of automation is a prerequisite for this approach.

Currently, the word “automation” has become a symbol of forward-looking production. It is obvious to everyone that the last 30 years have seen tremendous investments in this area. What profits do such investments bring? The answer to this question is not always obvious.

This document offers one solution of Tank Farm Automation.

1. A modern automated oil metering system gives the buyer leverage when negotiating with suppliers.
2. Real-time metering systems mounted on pipelines from processing installations provide an accurate balance of production losses. In addition, only in this case precise information on the operating efficiency of each installation is available.
3. An automatic blending system solves several tasks simultaneously: it allows a company to obtain the maximum quantity of high-quality product in the most cost-efficient manner.
4. Precise loading of products via filling scaffolds or flow meters provides for minimal losses and a good company image.

According to development countries statistics, the average oil refinery loses up to 6% of its oil during processing. The respective figure for western enterprises is 2%. Sale of this tremendous amount of product would not only pay for investments in a SCADA system, but also bring real profit. Today the share of Finnish and Norwegian oil products is very significant in the Russian Northwest. Their position will be even stronger after Russia joins the WTO. To compete with them successfully tomorrow, it is necessary to have highly efficient production today.

Correct automation allows elimination of the human factor. Thus, the transition to a new level is achieved – a level which was unattainable previously with manual control. This being the case, metrology accuracy requirements will climb rapidly as well. A high level of automation makes sense only when highly accurate measurements of production processes are achieved. Our system ***combines up-to-date metrology, automatic control and production process analysis.*** Here are the advantages of our system that result from this approach:

1. The system enables you to achieve maximum resource usage efficiency and the strictest product quality control. Experience in introduction of these systems shows that it is possible to cut losses twofold in this area alone.
2. The influence of the human factor decreases significantly.
3. The manager receives an efficient tool for controlling raw materials and products at the enterprise.
4. The system is based on an open architecture principle and uses open protocols. You do not depend on equipment or software suppliers. The system's operation logic is open to you.
5. The system is based on promising state-of-the-art solutions which, according to our expert evaluations, will be relevant throughout the next decade.
6. The system has a tremendous potential for extension and interaction with high level systems.
7. Each system element has been used and tested in field conditions.

Why are we developing this line of business? Combit (Combined Innovative Technologies) is a comprehensive engineering company introducing innovative technologies to the oil and gas industry. In this case, we combine several technologies. “Pure” automation without a system approach to metrology and analysis is not efficient. Therefore our activities are based on the following principles:

1. When choosing metrology tools, we try to use the most efficient, non-intrusive, best-in-industry devices.
2. When choosing fittings we can flexibly offer any combination from a large assortment of equipment from various suppliers. We have successfully solved challenges involved in the development and production of the necessary adapters.
3. Equipment offered by us is produced by world leaders, who can offer contractual support for 15 years.
4. We offer a wide range of consulting services in metrology in accordance with Russian and international standards.
5. We can train the customer’s personnel in our own training center, which is equipped with all the necessary equipment.

Combit is one of few companies experienced in production reconstruction by means of equipment automation. We have a well-developed field instrumentation service and diverse experience in local system start-up and full automation.

This offer describes the automation and metering system design philosophy, as well as the principles of instrument and control equipment selection. The described equipment variants and technical solutions are examples of actual, successful projects, which can be modified in accordance with the customer's wishes. We consider a customer to be our partner, so all your suggestions are very important to us.

2 THE AUTOMATION CONCEPT

Currently, most tank farm use local automatic controls and traditional instrument panels. Automation was based on the territorial principle, i.e. production area control and equipment status monitoring was implemented by panel devices and local system displays, located in control rooms distributed over the production area.

Integration of existing SCADA systems, built on the basis of equipment from various suppliers with various software, into one system often results in serious practical difficulties and does not allow the implementation of full tank farm automation. The functional and physical depreciation of existing instrumentation and automation tools, as well as modern requirements for production process automation (including industry safety requirements) encourage enterprises to implement full tank farm automation.

Full automation of tank farm should include two interdependent systems:

- ***SCADA providing for automated control of all process parameters in real-time***
- ***Automated Metering System (AMS) for static metering of production process results and generating a balance of raw materials and final products.***

In general, an automated metering system should be part of an enterprise's ERP system (corporate system for resource planning). However, we shall consider this as an individual system. This approach is true for any method of AMS realization.

The current level of automation equipment is such that it offers new opportunities for production process control and product metering.

A tank farm SCADA should provide for:

- collection of information, processing this information to fulfill technology regulation requirements and forecast the production equipment's status to guarantee its trouble-free operation;
- remote and/or automated control of production equipment that does not require the operator to be present in the production area;
- displaying and registering in the Central Control Station (CCS) all monitored production and equipment status parameters, their dynamic support and archiving during operation, as well as repair and start-up;
- generation of reports in the specified form.

A tank farm AMS should provide for:

- metering of incoming raw materials
- metering of produced and loaded product quantity

- metering consumption of raw materials, materials and energy resources
- metering the fulfillment of planned assignments for production and loading products and generating material balances for installations and production areas.

The maximum technical and economy effect can be obtained only by full automation of tank farm by:

- reducing equipment operation costs
- optimization of production site operation and improvement of product quality
- enhancement of control and metering efficiency, which leads to the reduction of production losses.

3 DESCRIPTION OF FACILITIES TO BE AUTOMATED

As a rule, tank farm are a set of several production areas, integrated by pipelines and a central control station. The following set of equipment is most typical:

- tank farms for receipt, storage and loading of products, including:
  - oil
  - oil product components for blending
  - commercial oil products.
- pump stations:
  - for blending oil products
  - for transfer of products within a production area
  - for delivering commercial oil products to railway and tank trucks to be filled
  - for transferring oil products via pipelines to other oil depots.
- stations for metering oil products:
  - delivered to oil depot via pipelines
  - loaded into long-distance oil product pipelines
  - loaded on railway tanks
  - loaded on tank trucks
  - delivered from production areas.

The specified facilities contain various systems for controlling oil product supplies in tanks, pumping units, auxiliary systems, sensors, regulating valves and various cut-off valves (with electric and pneumatic drives). As a rule, the total number of I/O signals for the control system of such facilities amounts to several thousands.

4 TANK FARM SCADA STRUCTURE

There is no typical tank farm design, so the tank farm SCADA structure should be developed individually for each enterprise. When doing so, it is necessary to use *typical solutions* for automation *of typical equipment* and typical production processes.

Any large SCADA system contains a multitude of local systems. To provide for their normal operation and the ability to add new systems in the future, the SCADA system should support the majority of common data exchange interfaces.

As a rule, *typical tank farm SCADA solutions* providing for equipment and production process automation should contain subsystems performing *the following functions*:

- blending control
- monitoring of product supplies in tanks (raw, components, commercial, etc.)
- metering of products delivered from production areas via pipelines
- metering of products loaded into railway tanks
- metering of products loaded onto tank trucks
- metering of products loaded into oil depots via pipelines
- metering of products loaded into long-distance product lines via pipes
- control of pump units
- control of cut-off valves
- control of auxiliary equipment
- fire fighting.

5 SCADA DESIGN PRINCIPLES

5.1 A tank farm SCADA system should be a distributed system

The tank farm SCADA should be a distributed system. A system is “distributed” if it contains several control centers distributed over an area. Such an architecture is used to preserve the performance capability of local facility control systems in case of a failure of high level control or loss of connection.

Designing a distributed system implies making decisions in real time on the equipment level, while strategy is determined by the higher level. Despite the fact that designing communication channels with a specified transfer time on the tank farm territory does not create any special problems, to enhance control reliability, it is necessary to ensure that the real-time commands do not depend on communication lines. Thus, in the nearest future, the use of smart sensors and actuators will become the most promising solution. Equipment modernization should be implemented gradually, so modern distributed control systems contain a smart sensor level, as well as PLC using older equipment’s analog signals.

A distributed system also implies distribution of process management, if necessary. A chief manager using a SCADA system can assign tasks and necessary resources to lower-level managers. Such a system implies a developed security system providing access to inner SCADA resources. The general SCADA structure is shown in figure 1.

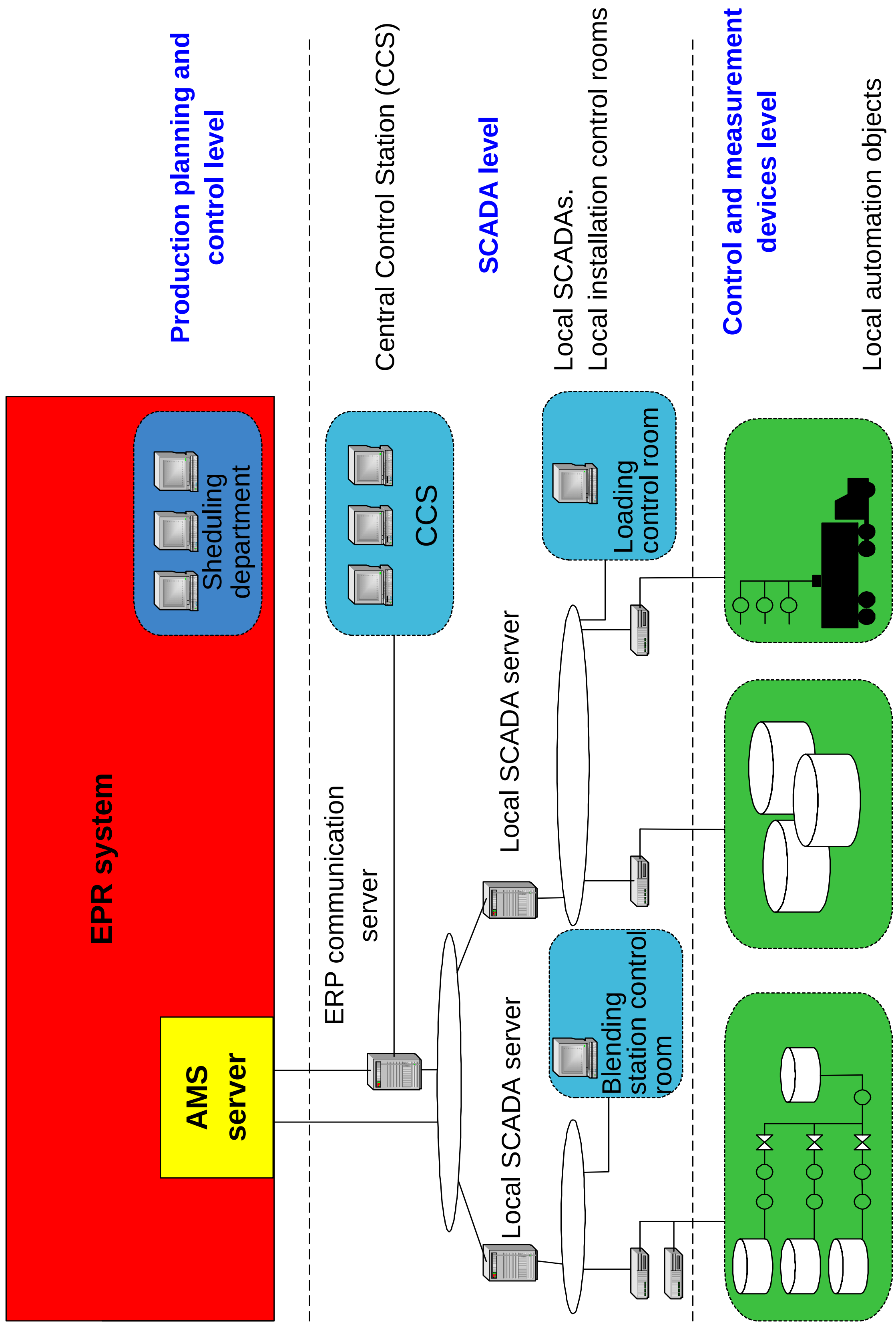
Production planning and control level
Central Control Station (CCS)
SCADA level
Local SCADAs.
Local installation control rooms
Control and measurement devices level
Local automation objects
EPR system
Sheduling department
AMS server
ERP communication server
CCS
Local SCADA server
Loading control room
Local SCADA server
Blending station control room

FIG. 1 SCADA STRUCTURE.

5.2 SCADA should have optimized control functions

The final objective of any industrial facility automation is improvement of control efficiency. Efficiency is achieved by the use of new data processing technologies, which are available at a sufficiently high level of automation.

The optimized control functions originate from the simplest PID controls. As a rule, a modern optimized control system is based on a mathematical model of facilities and uses a large number of diverse parameters. However, creating an ideal facility model is a challenging task. Therefore, a decision making support system (DMSS), in which a certain role is assigned to personnel, is currently among the most developed.

In the interactive mode, DMSS enables the operator to simulate various scenarios of production process control and chose the best process optimization criteria. In real-time mode, DMSS monitors the progress of various processes and the appearance of external influences, to ensure any necessary correction of programs performed by equipment level systems. Thus, DMSS performs only process optimization functions, and a certain independence from equipment level systems provides for secure system operation in case of failure of one of subsystems. This is in full accordance with the principles of distributed control.

If we use a blending system as an example, DMSS can solve the following tasks:

- Blending a product with a minimum margin in the main parameters determining a grade of gasoline.
- Blending a product with the minimum possible use of more expensive components for specified grades of gasoline.
- Providing the maximum quantity of product in case of shortages of components.

DMSS should optimize production process not only at local installations, but in the whole oil refinery, within the frame of the EPR system.

5.3 Loading assignment and report generation

Document generation implies generation of accompanying product documents for all types of loadings in accordance with current norms and generation forms (or changing the forms – with respective agreement on new ones). Documents should be generated on the basis of existing oil refinery sales systems, and should be made in accordance with loading and metering operations (balance keeping).

There are two different approaches to the generation of documents for loading. In the first case, loading documents are made in accordance with actually loaded product. In the second case, loading is made in accordance with the product quantity specified in the bill of lading. The first case is usually used by foreign companies; the second is more common in Russia. It should be noted that the first method has an advantage: as a rule, measuring a loaded product can be performed more precisely than dosing a specified quantity of product. This seemingly insignificant difference implies different interaction between an automated metering system (AMS) and tank farm SCADA. In the first case, SCADA is the master system, and the AMS a dependent one. In the second case, everything is vice versa. Thus we suggest using the first approach to the generation of accompanying product documents, as it is the most accurate and adaptable for correct operation of tank farm SCADA.

Therefore, the AMS should be the system monitoring tank farm SCADA operation. The basis of AMS operation is recording all operations for crude oil and oil product transfer. These records may form the basis for generating accompanying product documents and reports (per shift, day, ten days, month):

- availability reports
- transfer reports
- sales reports
- balance reports.

6 INSTRUMENTATION SYSTEM DESIGN PRINCIPLES

6.1 Custody transfer of products

One of the most important tasks of tank farm full automation is the custody transfer of products received and loaded.

The most common measuring method for custody transfer is a volume-mass method. This implies measuring volume and specific gravity under identical or standard conditions (temperature, pressure); mass is then calculated by multiplying these values.

Depending on the volume measuring method, the volume-mass method is divided into two: dynamic and static. The dynamic method is used when product mass is measured directly in pipeline by flowmeters. The requirements for custody transfer accuracy are met by volume and mass flowmeters, providing an oil custody transfer accuracy of 0.25% or better under certain conditions.

The static method is used when product mass is measured in calibrated containers. The product volume in tanks is determined by means of tank calibration charts; filling level is measured by level meters. Specific gravity is determined by measuring product hydrostatic pressure in the tank; this pressure is then divided by the level value. Another method is laboratory analysis of an oil product sample taken from the tank.

Vertical steel cylinder tanks calibrated in accordance with GOST 8.570-2000 [ISO 7507, ISO 4269] meet the requirements for oil product custody transfer accuracy (tank capacity measuring accuracy +/-0.1 -0.2 %).

Currently, a manual method of level measuring with a measuring reel is still used; this method should be replaced as it does not meet the requirements of full automation (manual measurement method), as well as safety requirements. Item 5.2.7 of “Industry Safety Rules for Oil Refinery Industries” ПБ 09-310-99 (approved by Gostekhnadzor of Russia) does not allow manual level measurement through the tank roof hatch with a measuring reel or rod. For this purpose, it is possible to use a custody transfer system based on non-intrusive radar level meters with a measuring accuracy of +/-1 mm. Such system measures product a quantity with 0.5% or better accuracy.

Such a system makes it possible to automate most custody transfer operations associated with receipt/loading of oil and oil products, namely:

- level gauging of oil product in tanks
- taking monthly inventory
- metering by tanks when oil is received via pipeline
- metering by tanks when oil is loaded into a pipeline
- check metering by tanks when oil is loaded onto railway tanks
- check metering by daily sales tanks when oil is loaded into tank trucks.

Trucks and railroad tanks are calibrated with an accuracy up to 0.5-1%. However, when large-scale loading or receipt of oil products is implemented, quantity errors for individual tanks make up for each other, and the resulting accuracy meets the requirements for quantity metering. To guarantee commercial accuracy when product is shipped to a consumer, it is possible to use an oil product metering method based on mass flowmeters or volume flowmeters combined with a densitometer. In this case, each standpipe of a filling scaffold should be equipped with such devices where the pipeline is connected to the header. Besides the main metering task, mass flowmeters should be used for filling capacity control. Tanks should be filled in a certain cycle. Prior to reaching a certain level in the tank, the product flow should be significantly lower (approx. 20%) than the maximum; near the target quantity, the flow should again be decreased to avoid overflow.

6.2 Measuring product properties for production process adjustment

Measuring product quality in automatic mode is necessary not only when loading a product, but also for production process adjustment. In general, it is impossible to determine all the qualitative characteristics of hydrocarbons online by methods specified in GOST. The use of existing devices in the production process can significantly increase production efficiency.

Compounding is the main stage where it is necessary to make rapid measurements of product quality. The sooner you receive results characterizing properties of gasoline obtained by blending, as well as component flow quality, the sooner the gasoline production process will be adjusted.

Currently there are two basic methods of automated online measurement of oil product qualitative composition. One is based on the use of distillatory kettles, another one uses IR analyzers. Use of distillatory kettles makes it possible to perform high-speed measurements on several flows simultaneously. Since all main parameters of products delivered to tank farm after processing are known, it is possible to obtain sufficiently accurate parameters using IR analyzers.

Depending on the hydrocarbon composition of raw materials and production processes, the gasoline can contain over 200 individual hydrocarbons of various structures; their combination and interaction determine the properties of gasoline. All main spectrum harmonics of major gasoline hydrocarbons belong to the IR part of the spectrum. Thus, the gasoline IR spectrum is a unique characteristic of gasoline, which makes it possible to determine qualitative indicators such as saturated vapor pressure, fractional composition, octane number, etc.

When analyzing the IR spectrum in order to obtain correct information about product composition, it is necessary to compare the spectrum with a calibration model (a set of spectra) of known composition. In turn, the calibration model should belong to a certain class with a similar hydrocarbon composition. In other words, it is impossible to create a universal model for determination of octane numbers for gasoline produced by various processes (cracking, reforming), or for various types of gasoline (e.g., it is necessary to develop different models for A-76 and AI-93 gasoline).

Thus, it is necessary to calibrate the IR analyzer in accordance with the production installation product spectrum. These costs should be added to the costs of equipment and personnel training. However, the advantages of the use of this device are obvious. For example, to guarantee maintenance of the product octane number on the level set in specifications, an oil refinery often provides for a positive octane number margin of 0.3-0.5, which can be reduced to 0.1-0.3 if continuous product control is performed. Simple calculations show that saving 0.1 of the octane number provides savings, or additional profits, of $400,000-$500,000 for an average oil refinery per year.

7 REALIZATION OF TANK FARM SCADA COMPONENTS

7.1 Blending control subsystem

Producing commercial products by blending in a header is the most progressive and cost-efficient method, whose advantages are widely described in literature. In addition, the economic effect of its introduction is confirmed by numerous data.

Figure 2 shows part of the continuous blending system with two headers; it demonstrates the principle of 'flexible production systems' which should form a basis of the designed blending station structure.

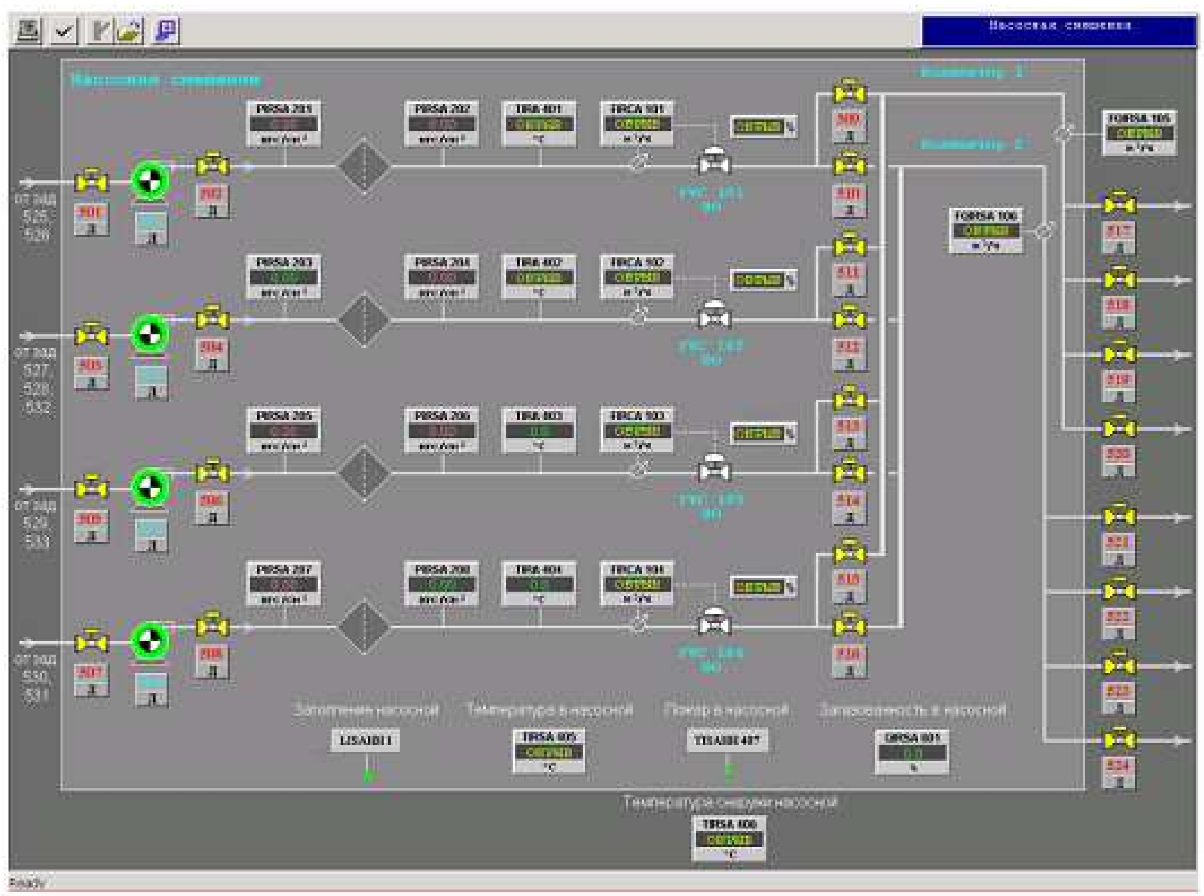

FIG. 2 Blending station.

The idea of the principle is that each header is connected with a component “line” equipped with flowmeter and adjusting valve (or frequency-adjusted actuator of the electrical pump motor). As shown on the diagram, the tanks are connected to cover all possible component set combinations when products are blended; the expensive measuring and adjusting equipment is used most efficiently, and the number of component “lines” is minimized. The range of component flow changes for each line does not exceed 1:20. Flow measurement accuracy in this range should not be less than 0.5%.

When a commercial oil product is blended in accordance with a recipe, the operator chooses the components (tanks) that should be used for this particular blending recipe.

When designing a blending station, it is very important to determine the overall station capacity and individual capacities for each individual component. In doing so, the same component can be delivered for blending various commercial oil products by different lines. For example, the high octane number component significantly varies in quantity for AI-80 and AI-95 gasoline; therefore, in some cases it is impossible to provide for correct flow measurement on one component line.

When a blending station block scheme is developed, it is necessary to provide for production equipment reserves for the future, in case new grades of lubricants or fuel will be produced.

A blending control subsystem provides for:

- entering the starting blend recipe with a component composition chosen by the production engineer in mass units;
- translation of component mass percentage into a volumetric one, and temperature correction of the current component flows revaluated to a specified temperature (if blending is made in volume units);
- preparation of the production scheme for blending (opening the necessary valves);
- activating pumps used in the blending process;
- assuring the specified system capacity;
- measuring current flows and the temperature of components and commercial oil product;
- stabilization (adjusting) of the specified ratio of components flows;
- correction of the recipe during blending from the production operator panel on the basis of laboratory analysis results (if necessary);
- automatic recipe optimization based on analysis of input components and final product (if the necessary equipment is available);
- displaying current and final results of blending on a monitor and printing these results;
- generating trends of adjusted parameters;
- registering emergencies and process lock-outs if they occur.

Blending of components is performed online simultaneously in one or several headers, resulting in production of one or several oil products. The subsystem automatically decreases productivity if there is a shortage of any component and stops blending by "adjustment error" if productivity by a component is not maintained. The subsystem also stops blending if the difference between total component flow and flow in a header exceeds a specified threshold. This operation algorithm prevents faulty production caused by the shortage of a blending component and/or failure of one of the flowmeters to maintain a specified accuracy rating.

Blending is stopped automatically by "dose" when the commercial oil product volume, transferred via the header, reaches a specified value.

Two versions of the blending production scheme are most common:

1) a blending station of continuous-cyclic operation, with component accumulation tanks; in this station, component contents in the composition are specified in % of ready product (***independent specification***).

2) a blending station of continuous operation, where some components are accumulated in the tanks, and the main component is delivered directly from the production installation to a commercial tank. Component contents are specified in % of the base component (***dependent specification***).

In both types of blending stations, the main components are delivered by centrifugal or gear-type pumps, and dopants used in blending, including viscous, toxic and low flow, are delivered by plunger pumps or leak-proof membrane pumps. The optimal method for adjusting flow in component lines equipped with gear-type and dosing pumps is changing the speed of the pump's asynchronous engines by means of variable frequency drives.

Blending station productivity is determined by annual (monthly) product yield; in our experience, a station should have a threefold margin of productivity. All production equipment is chosen in accordance with this requirement.

Analytic optimization system plays an important role in blending. If an online quality analyzer is available, the system can optimize blending by several parameters. For example:

- Calculation of components for preparation of the product with a minimal margin in the main quality criteria
- Calculation of recipes with minimal possible use of more expensive components for a specified product quality
- If necessary, maximum quantity of product if there are shortages of some components.

Mass flowmeters with an accuracy no less than 0.25% are necessary for measuring components and final products flows in a blending station.

To optimize component delivery paths to the blending header, the component lines, pipeline fittings in tank farms and blending pumping stations and the pumps themselves should be equipped with cut-off valves with power (pneumatic) drives.

7.2 Metering subsystem in a tank farm

All subsystems should meet the requirements of GOST 26976-86, "Oil and Oil Products. Mass Measurement Methods." The subsystem should use a measurement tool approved by Gosstandart of Russia and have a permit for its use issued by Gostekhnadzor of Russia.

In accordance with this GOST, mass measurement methods are divided into volume-mass and hydrostatic types. The volume-mass method meets modern requirements for measurement accuracy in a higher degree.

When the volume-mass method is used, the mass of oil product in a tank is calculated by multiplying the volume of liquid in the tank by specific gravity under the same conditions (temperature and pressure). The volume of liquid is determined by means of tank gage tables; filling level is measured by a level meter. The specific gravity of liquid is measured by an online densitometer or aerometer in a combined sample. The simplest and most efficient method of measuring the specific gravity of oil product in a tank at current temperature is the hydrostatic method based on the use of differential pressure sensor.

The subsystems provide for:

- receipt, processing, registering and displaying information about quantity of oil product in controlled tanks;
- automatic calculation of mass, volume, speed of emptying/filling the tank, level (for the hydrostatic method) of product in the tank (by means of gage tables and passport specific gravity). Specific gravity is also calculated if the tank is equipped with an optional differential pressure sensor;
- displaying parts of the production scheme, tank status, reference and calculation parameters on a monitor screen;
- archiving data for each tank in the form of the following relationships: "mass vs. time", "level vs. time", "volume vs. time", "speed of emptying/filling a tank vs. time", "specific gravity vs. time"; the data is stored for 30 days or more;
- generating alerts and indication of "preventive" and "emergency" high levels by calculated level values, or by a signal from an emergency overfill sensor; generating a control signal for closing the input cut-off valve with simultaneous switching to another tank or stopping the pump to prevent tank overfill.

As a rule, in a component tank farm, some components are stored in bullits – horizontal cylindrical tanks with a pressure up to 16 kg/cm^2. Each of these bullits should be equipped with a level meter (for bullits, the hydrostatic method produces a larger error than the volume-mass method).

7.3 Stations for metering oil products delivered from production areas via pipelines; loaded onto railroad cars and tank trucks; delivered via pipelines to oil tank farms and long-distance pipelines.

We suggest the metering of received and loaded products by means of most up-to-date methods: with ultrasonic and Coriolis flowmeters. As noted earlier, an alternative method uses high-precision volume flowmeters coupled with a densitometer. Total error in this case should not exceed the values specified in GOST 26976-86. The technical tools used should have appropriate certificates of approval and Gostekhnadzor's permit for using them in potentially hazardous areas.

The main advantage of an ultrasonic flowmeter mounted on a calibrated pipe is that it does not contact the measured flow of liquid. As a result, the flowmeter's parameters are stable and they are not affected by the abrasive action of liquid, and the flowmeter's operation does not create pressure loss. In addition, unlike mass meters, they have no moving parts, and therefore have increased reliability. Therefore ultrasonic flowmeters are the optimal choice for metering oil products delivered via pipelines from process areas to tank farm, where they should be mounted on each pipeline. When metering oil products delivered via pipelines to oil depots and long-distance pipelines, it is necessary to optimize the number of flowmeters. As a rule, this delivery is implemented via pipelines (200-500 mm in passage diameter) with high flows. Dividing the flow into several parallel flows at metering stations should be provided for at the design stage on the basis on economic considerations. Ultrasonic flowmeters have a larger throughput capacity than other types of flowmeters, and are therefore more cost efficient in such situations.

When metering products loaded at filling scaffolds into railroad tanks and tank trucks, it is necessary to equip each filling standpipe with a mass meter. Control over filling should be provided for at the same time as metering. Mass flowmeters are used with an adjusting valve providing the necessary characteristics for three stages of the filling process. The first stage of filling with an open jet is performed at a rate no greater than 1 m/sec, to prevent accumulation of static electricity. After submersion of the filling pipe into the product, the filling rate is increased up to nominal value. At the final stage, filling speed is decreased gradually to prevent hydraulic impact.

Completion of filling should be monitored by a filling sensor or by volume (redundant signal). It is recommended that the filling cut-off sensor on the tank be set manually for the following reasons: many types of tanks are in use (over 50), winter filling norms differ from summer ones, the tank sags during filling, filler hole volume may vary from tank to tank, and the volume of product drained off after the valve is closed may vary. Since it is impossible to automate opening and closing of the hatches of existing tanks, the level of automation for filling scaffolds used to fill railroad tanks is not impaired in principal if opening/closing of the hatch is combined with setting the filling norm sensors and reading the tank number.

The automatic filling system provides for:

- specifying the filling dose
- measuring mass flow
- stepped adjustment of filling capacity
- automatic termination of filling when a specified dose of product or maximum level in the tank is reached
- generation of a bill of lading for the tank filled.

All operations of receipt/loading of oil products should be accompanied by the automated generation of documents. A quality assurance and certification laboratory should be included in the general information network; this provides for entering data on product quality in documents. The sampling period, a form of data storage, a method of data exchange and other organizational issues should be solved during development of technical assignments.

Information on the quantity of received/loaded product should be delivered to the CCS and WKSs of metering stations, if they exist.

Metrological provisioning is very important for organization of custody transfer. Verification of all measuring tools should be specified and approved by Gosstandart.

7.4 Pumping unit control subsystem

The subsystems provides for:

- turning the pumping unit on/off (for pumping within the production area, delivery of commercial oil products to railroad cars and tank trucks, delivery of oil products via pipelines to other oil depots) as per the specified algorithm;
- indicating the pumping unit status (on/off) on the display;
- measuring controlled parameters of the pumping unit and electric motor;
- emergency alarm and pumping unit shut-off.

Blending pumping units are controlled by the oil product blending subsystem.

To deliver the main components for blending and pumping of liquid oil products, the pumps are operated in the following modes:

- *automatic (A):*
    - *primary (AP)*
    - *backup (AB)*

- *remote;*
- *local;*
- *shut-off* (repair mode).

Control mode switching is provided for by software.

All control modes are assigned by the operator from the control panel.

The control panel has mode selector buttons and control buttons. Current pump status is indicated by the color of the pump icon.

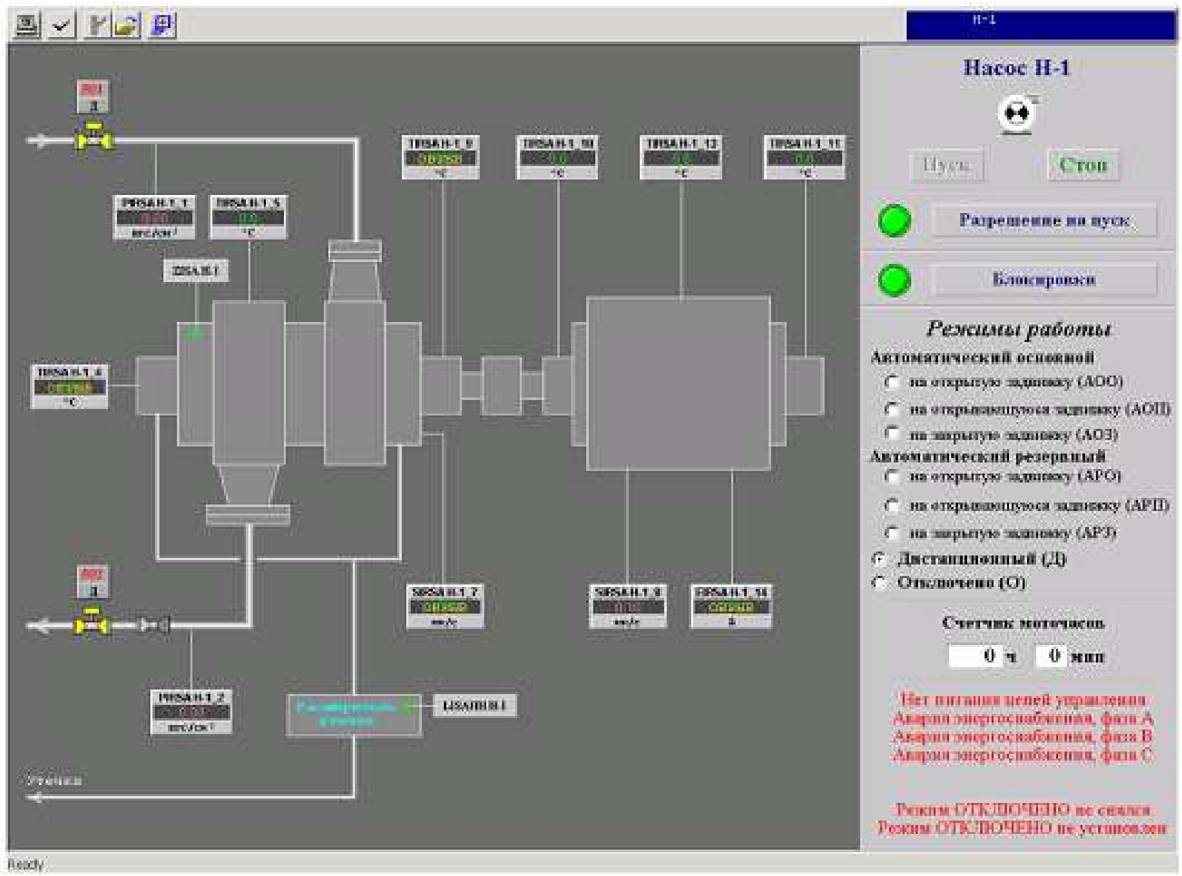

FIG. 3 Pump automation

Mode switching, switching date and time and all operator's actions are recorded by the control system and archived.

The switching algorithm is as follows:

- ➢ when one of the pumps is switched to AP mode, the other pump is switched to AB mode automatically;
- ➢ when one of the pumps is switched to AB mode, the other pump is switched to AP mode automatically;

- when one of the pumps is switched to *remote* mode, the other pump is switched to *remote* mode, too;
- when one of the pumps is switched to *shut-off* mode, the other pump is switched to *remote* mode automatically;
- when a power supply failure occurs with non-operating pumps that are in AP and AB modes, both pumps are switched to *remote* mode automatically;
- when a power supply failure occurs with an operating pump that is in AP mode, this pump is turned off and switched to remote mode; the second pump is turned on and switched to remote mode automatically;
- when a power supply failure occurs in a non-operating pump that is in AB mode and an operating pump that is in AP mode, both pumps are switched to *remote* mode automatically.

If any of the power supply phases fail for a period less than 4 seconds, the operating pump is turned on again. When any of the pump power supply phases fail for a period exceeding 4 seconds, the operating pump is turned off.

Pumping unit start-up is implemented in accordance with approved process regulations:

- for closed cut-off valve
- for open cut-off valve
- for opening cut-off valve.

In the *automatic mode,* the pump is turned on automatically in accordance with the specified algorithms.

In the *remote* mode, the pump is controlled by a computer from the control window. **START** and **STOP** buttons are available for pump control.

The pump units control subsystem monitors:

- pump control circuit voltage
- **SHUT-OFF** mode
- turning the pump on/off with a local **STOP** button
- turning the pump off by power protection circuit
- pump status: **ON/OFF**
- vibration of pump bearing and electric motor
- temperatures of housing, pump bearings and electrical motor
- oil product leakage through bearings
- electrical motor current
- input/output pump pressure.

These parameters are monitored by feeding the corresponding input signals (from sensors mounted on the pumping unit) into the control system. The subsystem responds when any of controlled parameters exceeds acceptable limits and performs the necessary actions to prevent an emergency.

7.5 Cut-off valve control subsystem

The subsystem provides for opening/closing cut-off valves with electric power (pneumatic) drives, displaying cut-off valve status, alarm and registration of emergencies.

The subsystem provides for the following modes of power drive cut-off valves:

- *automatic*
- *remote*
- *local*
- *shut-off* (repair mode).

Control mode switching is provided for by software.

All control modes are assigned by the operator from the control panel.

Mode switching, switching date and time, and all operator actions are recorded by the control system and archived.

In the *automatic mode,* the cut-off valve is opened/closed automatically in accordance with the specified algorithms.

In the *remote mode*, the cut-off valve is controlled by a computer from the control window. The **OPEN**, **CLOSE** and **STOP** buttons are available for control.

In *local mode*, the cut-off valve is controlled by locally mounted buttons.

"Smart" drives provide for the most efficient control of cut-off valves. Such drives offer a wide range of monitoring and control functions to the user. Optical isolators are usually used as an interface between inner drive logic circuits and remote control tools. Various control functions can be configured locally during installation from the configuration panel or remotely.

The following drive status information is available to the user:

- Intermediate or final position
- Torque switch actuation in intermediate position
- Drive is closing the valve
- Drive is opening the valve
- Output shaft is rotated by the drive
- Engine shut off
- Low battery level
- Drive is controlled manually (by flywheel).

The drives can be equipped with the following optional features:

- A controller which enables the drive to control (with 1% accuracy) the intermediate valve position proportional to analog current or voltage signal
- Current position sensor
- Optional position signal contacts
- Current torque sensor

- Interface providing for remote control and drive control via two-wire communication network
- MODBUS module for drive monitoring, control and feedback data transfer via RS485 communication channel
- Module collecting details of failures, position control and drive identification
- Signal relays
- Interruption timer.

7.6 Auxiliary equipment control subsystems

Depending on tank farm structure and the pumping equipment used, tank farm SCADA can contain subsystems that control the following pumping station auxiliary equipment:

- blowing ventilation
- extract ventilation
- pump electrical motor air cooling
- bearing water (oil) cooling pumps
- pumps for removing oil product leakage.

The control mode and algorithms for each subsystem are similar to those of the pumping unit control subsystem. They can differ slightly in number of I/O signals (usually the former subsystems use fewer number of signals).

The only exception is the blowing ventilation control subsystem (blowing ventilation automation circuit), since blowing fans as a rule are equipped with water heaters and louvers with electric power heating. Therefore, besides the above functions, the blowing ventilation control subsystem provides for:

- automatic control of air temperature in the pumping room by changing hot water flow in the heater;
- protecting the heater from freezing when the ambient temperature is below +3°C and return hot water is below +25°C, by turning off the fan and closing the cut-off valve. When the fan is turned off, an alarm should activate.

In addition, the control subsystem manages the following parameters in pumping station rooms and notifies of emergencies by alarm:

- pumping unit doors opening
- pumping station flooding
- temperature in pumping station and controller room, ambient temperature
- gas contamination in pumping station room.

7.7 Automatic fire-fighting subsystem

tank farm SCADA should contain an automatic fire-fighting subsystem (AFFS). The AFFS can be implemented as a separate system.

The AFFS monitors and controls the following foam fire-fighting equipment:

- pumps delivering foaming agent solution
- pumps delivering water for cooling nearby facilities
- tanks with foaming agent solution
- tanks with fire-fighting water supply
- equipment maintaining stand-by pressure
- drain pumps
- a system to adjust water temperature in winter
- electric drive cut-off valves.

The AFFS controls pumps and cut-off valves in foam pipelines in accordance with the specified algorithms.

When an alert signal is delivered from a beam sensor, a sound alarm is turned on, and the display indicates the sensor location. When two beam sensors generate the FIRE signal, the pump delivering foaming agent solution is turned on, the pump output cut-off valve is opened, the constant pressure maintenance cut-off valve is opened in fire-fighting networks, the foaming agent solution delivery line cut-off valve is opened (providing for delivery of foaming agent solution to the burning facility). If the operating pump has not built up the necessary pressure over the specified time, the backup pump is turned on.

The “Foam Delivery” sensor sends a signal indicating delivery of foaming agent solution to the corresponding facility. If the sensor signal is not received within the specified time, the backup foaming agent solution pipeline cut-off valve is opened.

For potentially staffed rooms, a delay in opening the cut-off valve is provided to enable personnel to evacuate. The light and sound alarms are turned on at the same time as the pump delivering foaming agent solution is turned on.

The subsystem:

- automatically maintains foaming agent solution temperature in winter
- monitors water and foaming agent level and notifies about the minimum (maximum) levels
- monitors the status of cut-off valves in foaming agent solution delivery lines
- monitors pump operation modes and cut-off valves, and generates failure alerts
- monitors pressure in solution pipelines networks and water pipelines and notifies about minimum pressure.

When a fire occurs at a monitored facility, the AFFS turns off all operating electrical power drive mechanisms of pumping stations and closes cut-off valves at pump-over lines and those located near the tanks.