Analysis of software and hardware technologies of information-measuring systems for environmental monitoring

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Abstract. The article presents an analysis of software and hardware technologies for information and measurement systems for environmental monitoring. The processes taking place in power plants of thermal power plants have different requirements for permissible emissions, which are measured using different criteria. Measuring and recording instrument data is an important part of a monitoring system. The analysis takes into account various monitoring technologies provided with a variety of tools, including up-to-date hardware and software systems. It is shown that the software and hardware technologies of monitoring systems should be implemented using real-time system software, have both hardware and software redundancy, as well as high security and increased MTBF.

1. Introduction
There are many different types of power plants in the world. These are, for example, solar, nuclear and hydroelectric power plants, wind generators, thermal power plants (TPP). It is this type of power plant that, when producing electrical energy and heat so much needed by a person, as a rule, harms both the environment and people who are (live) in the immediate vicinity of the thermal power plant.

Emissions of harmful gases, soot particles, etc. are constantly monitored by special monitoring systems of TPPs [1-4]. The creation of such monitoring systems is impossible without the use of special devices: sensors and gas analyzers. The development of these devices is also evolving, and even now many of these devices are smart enough to make the right decisions about the composition of harmful gases, the volume and size of particles, their temperature and other properties. However, all of these devices are located in a very aggressive environment. For example, inside boilers, chimneys, on components of technological equipment of TPPs, which are characterized by complex actuators, automation equipment and, often, do not allow sensors and gas analyzers to work uninterruptedly for a long time. Many of them refuse, give out false information. However, it is this information that is
necessary for automated flue gas monitoring systems to make decisions about what happens during technological processes at TPPs and how dangerous certain emissions from TPPs are for humans, and most importantly, what is their effect on the environment. From this point of view, increasing the information reliability of industrial and environmental monitoring of thermal power plants is an urgent research task.

In this article, on the basis of data on the subject area [5,6], the authors analyzed fault-tolerant specialized software models and systems that ensure the implementation of software and hardware monitoring technology in real time. Earlier, in [7-9], an analysis of technological processes of thermal power plants was presented, which have the greatest impact on the environment and, therefore, require monitoring of production and environmental indicators.

It should be noted that the topic under consideration will be relevant for many future years, since we cannot significantly affect the aggressiveness of the environment of technological processes at TPPs, and frequent replacement of sensors is not always possible due to technological difficulties and operating procedures of the power plant. Therefore, further intellectualization and information reliability of industrial and environmental monitoring will be an integral part of modern high-tech enterprises that produce electricity and heat.

2. Analysis of the research subject
Consider fault-tolerant specialized software models and systems that ensure the implementation of software and hardware monitoring technology in real time.

Today, there are many power plants, the processes taking place in which have different allowable emissions, which, in turn, must be measured using different criteria. Measuring and recording instrument data is an essential part of any monitoring system. There are various monitoring technologies provided with a variety of tools, including up-to-date hardware and software systems. Let us consider a class of systems used for monitoring pollutant emissions.

2.1. Hardware and software technologies of monitoring systems

2.1.1. Simple recorders (recorders). Simple analog devices have been developed and used for a long time and consist of a moving strip / disc with paper and a pen. A current or voltage is generated by the device and transmitted to the recorder and controlled by the movement of the handle. The result is a strip on paper with a pen mark representing emission levels [10]. The main disadvantages of these devices include the following:

- the number of channels (registered parameters) is limited;
- annotation to time and other information is filled in manually, which is prone to operator's (dispatcher's) errors and may have distorted information;
- the fixation speed is on average 20 mm / h, while the time scaling is fixed and cannot be changed after the trace is drawn.

2.1.2. Multichannel recorder. This type of device is capable of recording levels for many channels and accompanying automatic time annotation and calculations between channels (with normalization or averaging [11]). These recorders can provide multiple parameters (channels), and the data can be recorded on paper / stored in a limited amount of memory / downloaded to a computer at regular intervals.

2.1.3. Data loggers. Conventional data loggers are available for simple single dimension applications. These are digital replacements for an analog recorder. The data is stored in internal memory and can be displayed graphically or numerically. The device has the ability to download data to a personal computer (PC). Data processing is limited, only to provide normalization [11] or the formation of moving averages...
of the data [12]. More sophisticated data loggers have advanced functionality and are incorporated into PC-based systems.

The considered systems do not have sufficient capabilities for advanced data processing; they lack the ability to accumulate data.

2.1.4. Personal computer systems. Personal computers have many functions, most of which are of significant benefit to operators and regulators with emission monitoring requirements. Main advantages:

- high computing power for generating real-time moving averages and normalized measurements;
- massive data storage for both storage and access to long-term emission data;
- advanced interface capabilities for displaying emission data as needed.

2.1.5. Data transformation. Most sensors (instruments) generate analog signals that represent emissions data. For software processing of emission monitoring data, conversion of analog signals to digital format is required. Let’s look at two main conversion methods:

- Using analog to digital (A/D) converters, which convert analog signals to numbers. Depending on the type from A to D, this number usually ranges from 0 to 255 (8 bits) or from 0 to 4095 (12 bits) [13]. These numbers are then transferred to the PC via a standard interface in a standard format such as RS232 (RS485). Some of these systems can also be data loggers, providing data storage, alarms and real-time data transfer to a PC.
- Using an object communication device in which the instrumentation transmits real numbers to the interface unit, which then transmits them to the PC in the same way as described above. This system requires microprocessor-based instruments and digital data transmission. The way the signals are converted / transmitted affects the capabilities of the system.

2.1.6. Analog transmission / data conversion. Analog communication (typically 4 to 20 mA) requires correct input scaling. A/D can be scaled from 0 to 500 mg of the contaminant, the 4 mA position relative to 0 mg, and 20 mA to 500 mg. The transmitter output must of course be within this range. Range affects accuracy and must be chosen carefully: a range that is too small means that important data will be lost at levels above full scale; too wide a range means that the resolution at lower levels will be poor.

These systems can meet complex legal requirements. However, they do not allow the emission control system to be used as a diagnostic tool for instrument operation. In this case, it is impossible to send diagnostic data through the current loop, except in cases of a device malfunction, when less than 4 mA is transmitted.

2.1.7. Digital data transmission. When using microprocessor equipment, the data is already presented in digital format, at some stage of the measurement the analog signals will be converted to digital format. This usually occurs at a low level, meaning the instrument processes numbers rather than analog signals to calculate emission levels. The emission levels are transmitted to the PC via an interface. This digital transmission system can send much more information than an analog system, such as instrument diagnostics, maintenance indications, multiple moving averages, and raw and normalized data. This information can then be used to assess the performance of instrumentation and predict maintenance requirements, etc.

2.1.8. Software and real time data. When data exists on a PC in real time from an analog or digital source, the possibilities are limited only by the software in operation.

Operators need to know what the emission levels are for multiple moving averages in real time. Figure 1 shows a histogram of all measurements for one boiler. The data has been averaged and displayed in mg / Nm$^3$. Other averages and units are available for display.
Figure 1. Typical real-time monitoring data.

Recorders and base systems do not meet the need for recording emission information. Data analysis is either difficult or impossible and is limited to rough estimates from rolls of paper.

Figure 2. Scheme of monitoring parameters using software and hardware technologies.

Systems that transmit data to personal computers in real time may offer the best solutions to emission monitoring problems. Their capabilities for processing, storing, displaying and printing data provide the necessary monitoring requirements (figure 2).

Nevertheless, environmental standards require the modernization of existing production facilities and thermal power plants with the use of modern fault-tolerant monitoring automation systems.
2.2. Programming models and systems

Today, advanced technical means of automation, high computing power of end devices, broad capabilities of industrial communication protocols, as well as cloud technologies and computing have allowed developers and integrators of monitoring systems to focus on the development of software models and final software samples.

One of the SCADA class systems (Supervisory Control And Data Acquisition - supervisory control and data acquisition). This is a software package designed to develop or provide real-time operation of systems for collecting, processing, displaying and archiving information about a monitoring or control object. SCADA can be a part of an automated process control system, an automated power consumption control system, an environmental monitoring system, a scientific experiment, building automation, etc. SCADA systems are used in all sectors of the economy where it is required to provide operator control over technological processes in real time [14].

Since the monitoring parameters are the output parameters of a number of technological processes, these software systems have found wide application in the construction of monitoring systems, providing an effective system for supporting the technological process of removing flue gases and suspended particles.

Modern production or thermal power facilities all, without exception, have SCADA class systems. They are developed by both domestic and foreign companies. Consider the capabilities of common domestic SCADA systems, such as KRUG-2000 from NPF KRUG and MasterSCADA from InSAT, which have a large number of implementations, including at heat and power facilities.

2.2.1. Modular integrated SCADA system KRUG-2000. This system is a tool for building automated control systems for enterprise facilities, telemechanics systems, solving problems of energy accounting and dispatching. It is used to create distributed control systems and allows the exchange of data with real-time systems of KRUG-2000 controllers using internal, fault-tolerant exchange protocols.

Key features:

- Reliability. 100% "hot" redundancy of controllers, processor parts of controllers, modules and individual I/O channels (for SCADA with DCS). 100% "hot" backup of information networks, database servers and archives. N-fold reservation of operator stations. Automatic restart software and hardware (for operator stations and controllers). Highly reliable fault-tolerant communication protocol between SCADA and real-time controller systems. The possibility of storing archives on the controller and the presence of a telemechanical communication channel that provides data transmission over slow and unstable communication lines. Reservation of system time correction functions. Differentiation of access to system functions.
- Openness of the SCADA system. Support for international standards and specifications: TCP/IP (UDP), MODBUS, IEC 60870-5-101 / 104, OPC DA / HDA, COM, DCOM. Extensive libraries of drivers for various devices.
- Deep integration of SCADA and real-time controllers.
- Modularity and scalability of the SCADA system.
- Tools for creating and debugging custom projects. Object-oriented graphics editor and a large library of graphics primitives.
- Libraries of functions. The mechanism for creating User functions in C / C++ languages with the possibility of including them in the library of functions of the technological language KRUGOL™ [15].

2.2.2. Instrumental system MasterSCADA. This system has expanded tools for creating large distributed systems with the ability to use IoT technologies, the possibilities of using various hardware platforms and operating systems (OS) are applied, it allows you to create unlimited scale and complexity.

Key features:
1. Full vertical integration (programmable controllers, local HMI panels, operator workstations, servers, cloud services). One project - a single information space.
2. Wide cross-platform (Windows, Linux, Android, QNX, Elbrus, Unix).
3. Heterogeneity - the ability to use a variety of hardware platforms running on different operating systems within one project.
4. Object approach to project development. Objects are understood as a named set of graphical representations of a technological object, its parameters, monitoring and control algorithms, control windows and other available elements of the project (including other objects).
5. Full support for IEC 61131-3 [16] standard languages.
6. Unification of visualization systems. The main technology for the implementation of the graphical interface is the HTML5 standard.
7. Developed system of archives. Application of common DBMS (MS SQL, Oracle, Firebird, My SQL, Interbase, Sybase). The provision of archived data to the operator is possible in the form of trends, logs and reports.
8. Fault tolerance of the monitoring system (Redundant systems). Redundant set - two identical MasterSCADA programs installed on two computers. In the project, these computers look like one. One of the computers in the redundant system is MASTER, the other is SLAVE. The difference between the MASTER computer and the SLAVE computer is as follows - when the MASTER is started or the "Failure" sign is removed from the MASTER, the control is switched from SLAVE to MASTER (with the preliminary issuance of a message and its confirmation to SLAVE) [17].

3. Monitoring systems hardware

The technical support of automated control systems for technological processes, including the removal of flue gases and suspended particles, is formed depending on the tasks assigned to it, as well as on the degree of distribution of the system and can be represented both by programmable logic controllers and industrial computers (figure 3).

3.1. Industrial personal computers

These computer models are designed for industrial use and are used for collecting, processing and archiving data, solving problems of visualization, control and monitoring.

![Industrial personal computers](a) rackmount; b) to build built-in computer control and visualization systems; c) block execution.

Figure 3. Industrial personal computers: a) rackmount; b) to build built-in computer control and visualization systems; c) block execution.

Computers fully meet the special requirements of industrial applications:

- high degree of electromagnetic compatibility;
- high resistance to shock and vibration loads;
• compliance with national and international standards (GOST, DIN, UL, FCC Class A, ISO 9001);
• PC99 compatibility and optimization for Microsoft applications;
• continuous round-the-clock work;
• protection class from IP 41 to IP 65;
• peripheral devices have a long service life.

They can act as process servers, workstations, and also as a basis for visualization and process control systems.

3.2. PC Compatible Industrial Controllers (SoftPLC)

PC-compatible controllers differ from classical programmable logic controllers (PLCs) in that most of the functions that PLCs solve at the hardware level can be performed using software, including SCADA systems, under the control of various operating systems (see figure 3):

• DOS-like MiniOS7;
• real time Windows CE.NET 5.0;
• Linux;
• Windows Embedded Standard 2009.

![Figure 4](image)

**Figure 4.** PC-compatible industrial controllers (SoftPLC): a) compact design; b) a single structural unit; c) operator panel.

The presence of a built-in VGA video controller, USB, LAN ports, allows you to connect various peripherals directly to the controller and provide the necessary communication with other nodes of the industrial network. Possibilities of flexible programming by means of Visual Basic .NET, Visual C #, Embedded Visual C ++, SCADA. The possibility of using cheaper, more mature and faster developing open architectures based on a PC-compatible platform makes it possible to widely use such solutions for tasks where only conventional PLCs were previously used. The indisputable advantages of PC-compatible controllers are:

• low price of hardware;
• use of open protocols, which allows integrating devices from a wide range of manufacturers into one system;
• simplicity of programming and availability of a wide range of software, which minimizes the time and money spent on creating the system;
• simplicity of integration with higher-level control systems, which makes it possible to simplify access to data of technological processes from the side of enterprise management systems.
3.3. Programmable Logic Controllers (PLC)

Controllers of this type are shown in figure 5. They have an open architecture based on the operating system (OS), which makes them easy to integrate into vertically integrated development environments, in particular:

- Controller with HMI for local automation systems. The main areas of application of OWEN PLK63 are housing and communal services, central heating stations, ITPs, boiler houses, small installations.
- Built-in clock for creating real-time control systems.
- Embedded Linux OS.
- The increased number of serial interfaces allows connecting to the controllers a large number of equipments from different manufacturers with support for various interfaces / communication protocols.
- Possibility of embedding into vertically integrated SCADA and softlogic systems (for example, MasterSCADA, Entec, Cascade, Krug2000, etc.).
- Supports protocols ARIES, Modbus RTU, Modbus ASCII, GateWay.
- Free library of function blocks: OWEN developments: PID controller with autotuning, control unit for 3-position valves, etc.; standard libraries CODESYS.
- Expandable by connecting I/O modules.
- Increase in the number of discrete outputs by connecting the OWEN MP1 module.

All five languages defined by the IEC 61131-3 (IEC 61131-3) standard [16] are available for programming in CODESYS:

- IL (Instruction List) is an assembler-like language.
- ST (Structured Text) - Pascal-like language.
- LD (Ladder Diagram) - Ladder diagram language.
- FBD (Function Block Diagram) - Function block language.
- SFC (Sequential Function Chart) - State diagram language.

Figure 5. Programmable logic controllers (PLC): a) communication; b) panel, c) block type.

Today, high requirements are imposed on the systems for monitoring the parameters of the technological process, including the removal of flue gases and suspended particles:

- continuity of work (24/7),
- support for multichannel systems with calculated parameters,
- the ability to support archived data with a trend depth of several years, etc.
4. Conclusion
Thus, the software and hardware technologies of monitoring systems should be implemented using real-time system software, have both hardware and software redundancy, high security and increased MTBF. This approach is complex, and such solutions can be implemented by system integrators. However, despite the high class of security of technical measuring instruments used in monitoring systems, there remains a problem associated with the information reliability of the system elements and the reliability of the generated data, since the maintenance of the primary measuring instruments, including their verification, turns out to be difficult. This circumstance requires the improvement of methods for assessing the performance of the elements of the monitoring system and ensuring information reliability of the data generated in the system.

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