Control and visualisation of the selected industrial processes with the application of SCADA system

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The study presents the concept of control and visualisation of the operation of exemplary industrial processes with the application of SCADA system. SCADA systems and applications in various fields of economy were reviewed. Applications that perform the assumed visualisation, alarm, archive and protection objectives were proposed. The designs were prepared in Vijeo Citect environments. Due to diversity and versatility of the selected systems, the completed applications may easily be implemented in many actual locations irrespective of the pre-existing control systems.

KEYWORDS: SCADA system, visualisation, supervisory control, heat and power generating plant, woodworking, production of asphalt mixture

1. Introduction

Increase in the effectiveness level is required along with development of technology for generation of electrical and thermal energy from industrial plants. This objective is pursued on various planes, the most important of which is automation and adjustment of the system to the users’ needs. Monitoring and control with the use of synoptic boards in the extended control rooms was implemented in the past for this purpose. Currently, this role is taken over by SCADA systems which allow to improve and enrich the tasks completed in a traditional way [4]. Open, dispersed control and visualisation systems are characterised by big communication capacities as well as large potential in the field of modification and extension of the existing system. The characteristic feature of SCADA system is that the adjustment systems in a given technological process can operate independent of it, completing its basic tasks. The example of an enterprise which currently almost always bases its operation on the SCADA system is the heat and power generating plant. The complexity of the control system must take account of demand for electrical and thermal power as well as the possibility of further expansion of the heat and power generating plant without the need of creating the application from scratch. Thanks to the use of the SCADA system, this problem practically does not exist due to full scalability and large versatility of this system.
The next process raised in further part of the study is the technological process of woodworking whose scope of functionality may be modified depending on the specific case. For the purposes of the study the flow diagram of the structure of the process was assumed, which may be further developed and properly adapted. The last example described in the study is the process of production of the asphalt mixture, that is the substrate subject to subsequent final processing. The presented procedure may be implemented, after appropriate modifications, in the production processes of other component substances used for manufacturing of other components (sub-assemblies).

2. Characteristic of SCADA systems

The SCADA system (Supervisory Control and Data Acquisition) is executed in practice in the form of connected servers that archive data from the managed process and use it for visualization of its state and, after their analysis and processing, may also use them for controlling the process [2].

SCADA is the supervisory computer system managing the equipment connected to network, such as computers or equipment dedicated for industrial applications. It ensures control over equipment with highest priority of execution. Usually the equipment has its own programme which it executes. The operation algorithm or its parameters may be changed by the programmable logic controller (PLC) to which the equipment is connected. The controller’s programme may be fixed or controlled by the supervisory system, that is SCADA. In this way a three-layer control can be exercised over the task executed by the equipment. Owing to that, you can track current changes and react to them and in case of loss of connection with the rest of the system, this role will be taken over by the PLC [4].

SCADA systems consist of two main parts: hardware and application.

The hardware architecture includes [5]:
- dedicated server - MTU (Master Terminal Unit), which starts all forms of communication, collects data, stores information, sends the information to other systems and collects them from the users. It also communicates with peripheral equipment, such as monitors, printers and other IT systems. The main interface of the MTU’s communication with the system operator are monitors or touch screens on which the equipment comprising the managed process is presented on the synoptic images. The screens are refreshed along with the update of data in the system;
- data server, the objective of which is making available the data obtained from measurement equipment, client stations and other servers. The data is usually properly processed before;
data collection equipment. PLCs are most frequently used for this purpose. The less popular solution is the RTU (Remote Terminal Unit). It collects the information from various input equipment, such as pumps, alarms, meters, etc. The data delivered to it may be both analogue (actual values), digital (0 or 1) as well as pulsation. Many units collect the information in memory and wait for request from the MTU to send them. A microprocessor which can directly control the process without communication with the MTU is built-in in more advanced RTU solutions, and in case of recognizing its address in the node, it receives the command from the dedicated server and executes it; client stations, which enable interaction of the user with the system. They ensure visualisation of the process, its control, review of events, reaction to the system or tracking the reports. Small networks use one server performing all the functions. In bigger applications with big amount of data processing may be dispersed in order to reduce the load of individual computers.

In order to ensure continuity of the effective operation of the system it is recommended to use redundancy of some of its elements. SCADA systems use the following redundancies [6]:

- file server:
  The data are not lost in case of failure. During its operation, the system must save the data in two locations at the same time or perform synchronisation with the current server in line with the planned schedule. In order to ensure the effective reliability, basic and redundancy servers shall be powered from separate electrical circuits or placed in separate rooms, if possible;

- transmission channel:
  After breaking of the transmission channel, the signal from a given equipment may be sent with a different channel. This solution is specially recommended in case of sensors testing parameters of factors with critical significance for the process;

- I/O server:
  The spare I/O server prevents loss of information from the sensors about the current state of the process and ensures the possibility to influence its state. Rules of caution should be exercised, as in the case of the file server;

- LAN networks:
  Damage of the LAN network, depending on its configuration, may lead to lack of the system’s connection with some of its parts. Provision of the second working network enables further operation of the system owing to operational communication;

- server:
  The main server has strategic importance for the whole system. Its redundancy enables quick restart of the whole system in case of failure of the
basic server, without unnecessary stoppages of the process. Rules of caution should be exercised, as in the case of the file server.

3. Tasks and applications of the SCADA systems

Functions performed by the SCADA systems include [7]:
- collecting and processing data coming from the process,
- visualisation of the state of the process,
- control,
- alarming and recording the events,
- archiving data,
- making available the information about the process in computer networks,
- reporting,
- protection of access (user service – authorization system).

The use of SCADA system enables:
- reduction of operating costs,
- ensuring current knowledge about the system’s efficiency,
- improvement in the system’s effectiveness,
- longer life of equipment,
- reduction of the time needed to identify damage and its repair,
- using time spent for observation of the system by the service staff on execution of other tasks,
- easier management of the facility thanks to automatically generated reports.

Figure 1 presents main fields of application of the SCADA systems. The tendency in which both the users and suppliers (distributors) indicate generation of energy as the most frequent area of SCADA systems application can be observed. The option “others” (in Fig. 1) includes, among other things [8]: pharmaceutical industry, automotive industry, laboratory systems, automation of buildings and production of electronics.

The automation systems are still necessary for greater number of applications and industries. There is a big selection of solutions offered by various suppliers. The market of SCADA systems in Poland is still highly receptive. These systems, so far associated with manufacturing plants and industry, currently more and more frequently supervise the systems in the plumbing industry, system of intelligent buildings, the operation of solar power stations, monitor the consumption of electrical energy, and are much easier to operate.

Various criteria can be used during designing of SCADA systems, depending on the existing state of the facility or the investor’s requirements. Three basic designing approaches can be distinguished [4]:
- territorial:
Individual synoptic screens show the information concerning the equipment or its group located in small distance from one another. They are often managed by one controller, which limits the complication of data exchange in the network;

- technological:
  Data are grouped with regard to their association with a given fragment of technology, even if they come from parts of the plant which are distant from one another, in order to present the information concerning a given issue in full. This results in bigger complication of data exchange in industrial network;

- hierarchical:
  The operator may move from the screens presenting the whole process to the views presenting its individual sections in detail.

![Fig. 1. Main application areas of SCADA systems [8]](image)

### 4. Design assumptions

The objective of the study is the development of SCADA systems enabling management of two-block heat and power generating plant, wood processing system as well as asphalt mixture manufacturing process.

The object of the first study is municipal heat and power manufacturing plant which supplies the heat for heating and technological purposes of the industrial plants located in its neighbourhood. The demand for household heating is seasonal, however, the demand for industrial heating occurs during the whole year. Due to that extra coal-fired peak load water boilers WP-70 are used in each block for generation of the increased volume of heat in the autumn and winter season. The capital expenditure for them is almost about 40% smaller than for high-pressure steam boilers OP-140 used here as basic boilers. In the study, diagrams of heat units BC-30 with cold reheat of the steam (Figure 2) using the
combined generation of electrical energy and heat were applied. Steam boiler OP-140 with the capacity of 140 t/h as well as extraction-back-pressure turbine set with electrical power of 30 MW are part of the block. District water heaters are powered from the back-pressure outlet and the last negative source. Water boiler WP-70 may supply the heat with the power of 80MJ/s. The block also comprises the set of feed water pumps and the carburization system [2].

The second example presents the design of the application supporting the woodworking process. In this solution, all the wood which is to be subject to processing must be entered into the system’s database. If there is no wood in the database, it does not exist for the process. The wood is accepted to the warehouse and then subject to two-degree processing. Then it is transferred to the warehouse again, waiting for its collection.

In the third example, the visualisation and alarming system was implemented in the process of asphalt mixture production. The implemented safety process connected with user database allows to protect the application against unauthorised use. The selected actions of the operators are reported in *.rtf files and text files. Individual phases of the process are shown on the separate graphic pages of the application. In each modern asphalt plant the occurring processes are complex and extended, therefore in this example the authors presented the representative example with the necessary minimum of operations and equipment.

All the executed SCADA applications are described in more detail in next chapters of this study.

5. Design of the SCADA system for heat and power generating plant

The authors proposed the exemplary application of the SCADA system on the basis of the newest product Vijeo Citect 7.40, which – apart from typical functionality identical with other analogue systems – is also distinguished by the ease of simulation of the operation of the actual system (with specific PLCs) with the possibility of quick switching to the operation in the target location. This allows for the effective testing of the solutions before their implementation in practice as well as easier works in connection with potential extension of the control system to include new equipment and/or controllers.

The proposed application comprises the following synoptic screens:

- login page: enables logging in and out, adding and editing the users (only for users with administrator rights) as well as closure of the application: data of the logged in operator, co-author of the article, are visible on synoptic images from Figures 2-5;
- main page of the process (Fig. 2): includes the view of the whole process as well as the values of the most important parameters; buttons enabling moving
to relevant sub-page (card) including more information and the extended possibilities of control can be found at individual elements of the diagram;

Fig. 2. Main screen of the visualisation system of the heat and power generating plant operation

- carburization pages (Fig. 3): visualisation of coal feeders, mills and fans can be found there; the user has the possibility to switch on and off the belt and the mill; he/she can also set the values of the coal flow as well as the capacity with which individual fans should operate; these pages also include coal flows drawn in real time;

Fig. 3. View of the synoptic screen of carburization of boiler No. 1
boiler pages: include visualisation of boiler operation, display of the values of temperatures from the sensors: water flowing to the boiler, output steam, combustion temperature; you can switch on and off the burners in the boiler as well as view the temperature of output steam drawn in real time from the level of this page;

feed water pumps pages: present control systems of the feed water pumps; show readings from pressure sensors downstream and upstream each of the pumps, the operation of which is cascade and operated via events;

exchanger pages (Fig. 4): on these pages the user has the possibility to look at the operation of exchangers of technological heat and household heat; control of exchanger operation may take place by the impact on the operation of the feed water pumps and condensate pumps; these pages present the results of measurements from temperature sensors at the input and output of each of the exchanger and de-aerator;

Fig. 4. View of the page of exchangers of the first turbine set

turbine set pages (Fig. 5): they display the values of pressure sensors and the steam flow at the input/output of the turbine as well as the values of active and reactive power; the operator has the possibility to set the field current of the generator, through which he/she influences the current value of the reactive power; in the background, the function calculating the value of generated active and reactive power is executed and their flows are drawn; the pages also include the buttons used for synchronization of the generator with the network or its disconnection for the purposes of individual operation;
Fig. 5. Visualisation of the operation of turbine set No. 1

- alarm pages: include all the registered analogue and digital alarms, the time of their occurrence as well as the names of variables which caused their occurrence; the threshold that caused the alarm is also assigned to each analogue alarm.

34 digital process variables, 92 actual process variables, 12 trend variables, 6 digital alarm variables and 38 analogue alarm variables were declared in the design.

Moreover, 4 periodical events used for cascade control of feed water pumps in each of the blocks were implemented. The privilege system connected with the list of target users (operators) along with keyboard shortcuts facilitating navigation on individual pages of the system was also implemented.

6. Control and visualisation design of the woodworking process

The basis for the design is the technological woodworking process with the consideration of logistics of raw material transport. Timely supplies of wood for processing as well as the acceptance of processed material in a way preventing hold-up constitutes key economic assumption. The process consists of four main stage:

- acceptance of wood to the warehouse,
- cutting the wood across,
- cutting the wood along,
- delivery of the wood.
The technological process was designed in such a way to clearly show generation and transmission of the signals in similar systems. Hence the main assumption is illustrating the process of creating the control algorithm and the method of its implementation. Figure 6 presents the algorithm of operation of the technological process.

Fig. 6. Block diagram of the woodworking process of the batch of wood
The algorithm does not show simultaneous operation of the whole system because the system is multi-themed. It can process many processes and perform many functions at the same time. When one batch of the wood is processed on the frame sawing machine into the final product, the cutting-across system may already process the next batch of the product. At the same time, you can add the wood to the warehouse and remove the wood after processing. It should look like that in case of the physical process. Each batch of the wood is recorded in the database, while after processing the record is executed in the second database containing only the processed wood, ready for dispatch.

One of the two main pages of the design is the view of the warehouse part presented in Figure 7. It shows the state of storage and the associated elements in real time. On the left side of the warehouse there are batches of raw material, ready for processing, while on the right side you can see the processed wood, waiting for acceptance. The numbers presented near the state designate the percentage filling of the warehouse by a given type of goods or by all goods, which can be observed on the progress bar found over the warehouse. The design uses two databases containing stocks of wood: processed and unprocessed.

On the right side of the screen you can see the diagram showing the dependency of the wood stock in the warehouse from time. The sampling time of the diagram amounts to 1 second. There is a possibility to display the diagram on the new page. The synoptic window showing the diagrams was presented in Figure 8.
Over the diagram, in the warehouse window, there is also a section of the operator panel. It allows to accept the raw wood to the warehouse and remove already processed wood. Each of the operations can be conducted in two ways: manually or automatically.

Fig. 8. Diagram of wood stocks in the warehouse in the function of time

The second main screen of the design is woodworking. It was presented in Figure 9. The process will begin when the machine is in good working order (signal from the controller) and will be started by the operator with the use of the button. Material processing consists of two parts: cutting the wood along by the circular saw or processing it into boards or beams with the use of frame sawing machine.

The first processing phase, that is cutting the wood across, is shown on the left side of the screen. When the machine is in good working order and is switched on by the operator, it collects the batch of raw material from the warehouse. The wood appears on the extreme left side of the conveyor belt and is transported to the right, in the direction of the disc. It is then cut into two parts. The top part is immediately conveyed to the discharge warehouse, while the bottom one must be pushed up. The actuator arm is started for this purpose. The actuator is triggered when the bottom diodes detect the presence of goods, while the top ones do not. It occurs when the top log goes beyond the range of detection of the location diodes, while the top log is in the transfer location. The actuator pushes the log to the conveyor which is located higher. From there it is transported to the discharge warehouse. Figure 9 shows the process of transporting the log from the bottom to the top.
This process is carried out for the appropriate number of cycles. When the number of cycles to be completed falls to zero, the wood is transferred to the second part of processing, in line with the algorithm shown in Figure 6. If the frame sawing machine does not work (it is switched on and waits for the batch of raw material), the wood is conveyed to it for further processing. In other case the batch must wait for release of the frame sawing machine. In this time, part of the cutting-across process is not active due to filling of the discharge warehouse.

![Woodworking window](image)

**Fig. 9. Woodworking window**

After transporting the wood to the frame sawing machine the rounded walls are sawn off and the wood is cut along to receive the desired shape. Each product from the frame sawing machine moves to the right on the conveyor belt. The waste is stored on the top of the screen, while the final product on the bottom. After the completed process, the wood is transferred to the warehouse, where it waits for acceptance by the orderer.

There is a possibility of quick processing of the batch of wood by pressing the “Acceleration” button. This results in switching off the machines and automatic processing of the oldest batch. This is the option created solely for the purposes of quick tracking of the whole process. It allows to dynamically observe the stocks of individual goods in the warehouse.

### 7. Design of management of asphalt mixture production process

In the modern asphalt plant you can distinguish the basic components described in [1], such as: paving machines, batchers, dryers, dust collectors, sorting machines, weighbridges, mixers.
The diagram of the simulated installation in the visualisation and control system was included in Fig. 10.

Fig. 10. Diagram of asphalt production system: 1 – conveyor belt, 2 – gathering conveyor with weighbridge, 3 – feeding conveyor, 4 – burner, 5 – fan, 6, 7 – screw conveyors, 8 – sieves, 9 – pump, 10 – heater, 11 – hoisting winch

The main assumption of the design is to create visualisation of the process of manufacturing the bituminous mixture.

The design includes:
- the possibility of control of all the equipment taking part in the technological process,
- the possibility of changing the working formula,
- protection against overfilling of the tank for finished mixture,
- protection against incorrect switching off of certain equipment taking part in the process,
- users with different authorisations,
- possibility to save the activities conducted by the user in the external file,
- saving the reports on the volume of mixture added to the finished mass tank as well as report on the volume of mixture loaded onto truck,
- possibility to simulate the essential conditions and events (for the purposes of testing).

The application was executed in CitectSCADA programme in version 6.10. The designed control and visualization algorithm comprises the following functionalities:
- determining of the formula,
- switching on the sub-assemblies,
- weighing and potential heating of relevant volume of substrates: bitumen and extra substances,
- collecting and preparing the aggregate,
pumping the bitumen and transporting the aggregate as well as additions to the mixer,

mixing the components and transport of the finished mass to the selected tanks,

alarming in case of: lack of aggregate, overfilling of the screened aggregate tank, filling of the finished mass tanks.

The main page of process control was shown in Figure 11. Individual phases of the process are also available on separate graphic pages. The exemplary view of the mixer was presented in Figure 12.
The occurrence of the emergency situation results in generation of the window with the relevant warning message, graphic signalling in the appropriate place of the synoptic image as well as saving the information in alarm database along with its simultaneous display on the special alarm page. 80 process variables, 5 digital alarm variables, 2 analogue alarm variables were created in the designed application. Control is based on the system of 15 events and 16 control functions written in the dedicated CiCode language.

The application comprises the sub-programmes controlling all the sub-assemblies of the production plant. In the physical execution of the design control signals are sent from SCADA application to the controllers and regulators, with which individual elements of the production plant are controlled. Also, all the signals from the sensors are sent through the controllers to the application, where they are processed and used in the control process. 75 actual signals occurring in the system comprise:
- 32 analogue control signals, from which 27 are analogue inputs and 5 are analogue outputs;
- 43 digital control signals, from which 19 are digital inputs and 24 are digital outputs.

The objective of the PLCs in the presented system is control of digital outputs (opening/closing the gate valves, switching on/off the conveyors, etc.), transmitting analogue and digital signals from the sensors to SCADA programme, control of analogue inputs with the use of the inverter. In order to adjust the bitumen temperature PID regulators shall be applied, which switch on or off the bitumen heating system under specific conditions. Tensometer scales are used to weigh the relevant volume of components. The gate valves are opened and closed with the use of pneumatic actuators. The speed of movement of the belt and feeders is regulated with the use of the inverter (e.g. Sinamics G110 – CPM110).

8. Conclusions

The objective of the authors was to show versatility of SCADA systems applications on the example of three different designs: management of the operation of the heat and power generating plant, woodworking system and asphalt production process. This was carried out by execution of the application in Vijeo Citect SCADA programme.

The use of SCADA systems is justified even with smaller networks due to the possibility of supervisory control over the process, with the use of equipment coming from different manufacturers. The use of events and analysis of archive data also enables automatic management of the process in emergency situations. The cost of implementation of such an undertaking is relatively low compared to
the prices of production equipment, owing to which such execution may bring considerable profits in the longer operation period.

Currently, SCADA systems are used more and more frequently in practice. They are popular in all fields of industry in which there is a need of control, visualization, archiving, alarming and protection of access to the given process or the whole undertaking, sometimes even dispersed in the large space.

CitectSCADA system is intuitive to use and allows to solve all the engineering problems. The additional advantage of this software is a very extensive help system as well as the possibility of cooperation with all the PLCs in the world. It is frequently used in many locations all over the world, beginning from small to very complex systems.

References


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