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PC based data acquisition, monitoring and controlling techniques in wastewater treatment processes

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Abstract. One of the most important functions of an automated system is to provide information about the process status. The acquisition, manipulating and monitoring of process data as an important component of these function, is not limited only to a passive state, but involves also, some intervention of personnel that supervises the process. In case we are speaking about a wide-spread area system, the efficient data monitoring can only be possible if hierarchical and distributed systems are used.

Key Words: monitoring, acquisition, SCADA, wastewater, treatment, PLC, dispatcher, VPN.

Introduction. Generally speaking, data acquisition is the process of collecting data from the real world [1]. In most cases, for scientists and engineers these data are in numerical form, and are collected and stored using PC based systems [2]. The usage of such systems presents the advantage of large amount data storage possibility, in a short time, with a minimal error rate. In order to be stored and manipulated by the system, these data must be in a digital format. All signals have to be translated into numerical values collections, with a higher accuracy, resulted from sampling procedures, applied to analogue signals. These results in providing numerical values corresponding to certain time period (analogue to digital conversion). Once collected and stored, these data are manipulated by specific application (as SCADA systems), and delivered to the end-user (operator) in a specific format like trends, reports, diagrams and so on [3, 4].

Data acquisition and processing. The wastewater treatment processes have complex structure and involves a variety of specific process parameters [2, 4]. In purpose of process monitoring, it is necessary to transform these process values in electric signals that will be sent to the corresponding equipments. In the section below, we will discuss about the aspects like reading and transmitting these signals from the field to the main units.

Process parameters. Specific electrical signals and the transmission method. In purpose of highlighting some of the specific process parameters we will consider an example of a typical wastewater treatment plant that processes residual public wastewater from a typical urban environment.

From the beginning of the process flow, we have to know the water level in the mechanical treatment process area. Next, in the chemical treatment area, there is need of some specific parameters like pH, flow rate, water level. Corresponding to the biological treatment stage, there will be water dissolved oxygen transducers, chemical oxygen consumption, turbidity and total sludge saturation (TSS). Also, for the water evacuation stage, there will be other specific parameters like flow rate and pH. During the process flow there can be a lot of other parameters involved, like ozone concentration (if there is ozone treatment involved), or ammonium concentration and high temperature transducers. This situation can occur depending to the process particularity, as we can consider an industrial wastewater treatment for the situation above.

Considering the type of electrical signal provided by the signal detectors transducers, we can generally speaking about two types of signal, digital and analogue. In most cases, digital signals are the expression of certain level detection, like water or sludge level, pressure or temperature level and so on. Most of the detectors used in such situations have the possibility to adjust the detection level of the input measured value, together with other extra functions like hysteresis or timers (on/off delay). Moreover, many detecting devices acts as signal transducers, providing analogue signal corresponding to their input values. Regarding the electrical format of the analogue measurements, provided by the transducing devices, there can be two differing situation we can talk about. The common situation is the unified output signal, and digitally coded output signal, according to the transmission protocol used. Commonly, the transducing devices that provides digital coded signal, provides also analogue unified signal to its output.

Using the digitally coded signal method, give significant advantages especially when considering transmission network architecture. The data transmission protocols give the possibility to connect all the terminal devices (sensors or even actuators) on the same line in a serial configuration, thus eliminating separate connections from each element to the central field unit. The digitally coded signals transmission support is according to commonly used protocols, like serial (RS232, RS485, RS422), or Ethernet according to TCP/IP protocol.

In the situation of signal transmission along big distances, there can be used wireless equipments. In this case, the commonly used solutions is represented by GSM modems or radio modems. In the first situation, the physical transmitting support is the GSM network, and in the second, the equipment involved are using a direct duplex radio connection between stations.

As an example, we can consider a data transmitting systems connected to a SCADA server, according to the drawing below. As we can see, the physical values are transformed into electrical signals using various types of signal transducers. These electrical signals are connected to the input of field PLC units (Programmable logic Controller) that are running the local process control. Beside this, the PLC units are transmitting the signal received from the transducers to the radio-modem units RM1 or RM2. This can be done according to the data transmission protocol used, like Ethernet (TCP/IP) or serial (RS232, RS485, RS422). If needed, the radio modem units may act as repeater if transmitting line extension is needed, or due to difficult terrain conformation, as we can see in the situation of RM1 in the Figure 1. At the reception, another radio modem unit will receive the signals from all other connections and will deliver the data coded signal to the SCADA server.

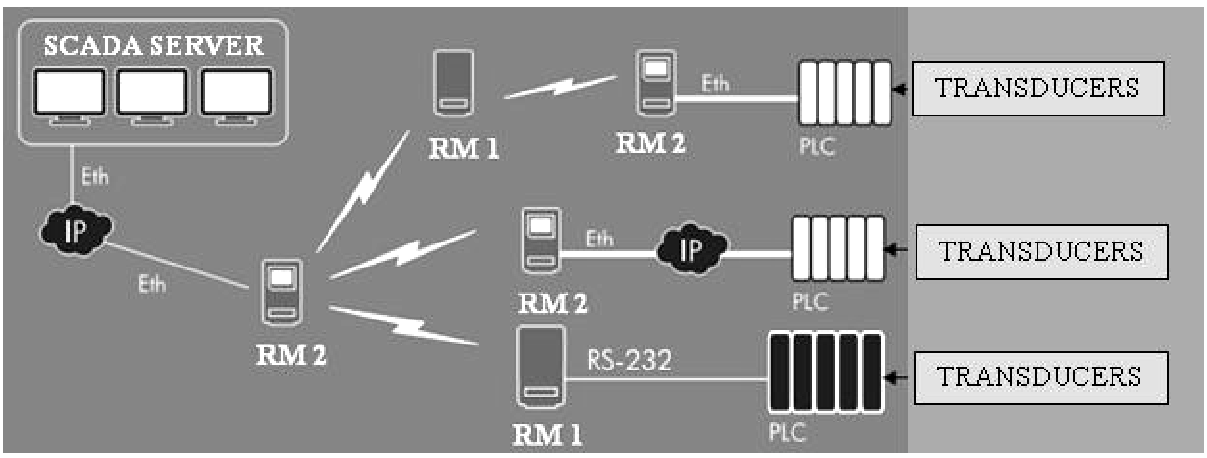

Figure 1. Wireless data transmission to a SCADA server using radio modem equipments.

Another method for transmitting digitally coded data is using optical fiber support, whenever this is possible. The main advantage in this situation consist in very good immunity to electrical noise and a wider frequency band for data transmission, much wider than previous situation of using radio modems. Obviously, in this situation conversion equipment (media converters) will be needed, to ensure electrical to optical signal conversion and vice versa.

Signal processing. The electrical signals transmitted to SCADA server as described above has to be treated and processed separately by the system. This can be done by using a tag system, each process variable being associated to an internal system tag, defined by specific parameters, as we will see below.

In order to have reliable tag identification, there is need of declaring at least four specific characteristics (parameters) like tag name, I/O (input/output) device name where tag belongs to, memory address, and tag data type. The data types commonly used in declaring a tag can be digital (Boolean values, especially signals from detectors), one byte integer, 2-bytes integer, signed or unsigned, 4-bytes long integer signed or unsigned, real(floating point on 4 bytes), or as a string maximum 256 bytes. There can be also auxiliary properties like raw scale, internal (local) scale, measuring units, formats and so on.

By using a proper coordination between raw scale and internal scale, we can increase the measurement accuracy by restricting the measure reading range to the real field values. We will consider a situation where a transducer has a wider measurement range than process values range; in this case we will restrict the output reading interval from the transducer only to the working interval, according to process measurement range. As an example we may consider an analogue output signal provided by a pressure transducer that is sampled and digitally coded as a 2 bytes long integer data type. In this situation, the reading will have a raw scale from 0 to 65.535. This will correspond to the entire pressure range read by the sensor, which may be 0...10 bar. If the real process values will be only between 0 and 6 bars, then the local scale can be associated with the corresponding raw scale values, between 0 and 39321. This method has an accurate applicability if the process value is expressed as a percentage from maximal possible value.

These values will be processed using various methods, according to the requirements, in purpose of providing desired process information to the user. One of the most used methods is the trending, where the values are graphically represented as time function. Using trends, there can be highlighted some process variations and its dependency to the other parameters or external factors. Most of SCADA environments have the possibility of long-time trend data recording; with useful and powerful process analyze instruments like Pareto charts.

Another important feature that process data processing is providing consists in managing the process alarms. Mainly, the process alarms can be defined as distinct variables derived from the main tags(variables), but with certain specific properties that will facilitate the alarm management. The same as process variables, the alarm types can vary from one SCADA system to another, but mainly there will be two types, analogue and digital. The analogue alarms will track the analogue tags, and it will change their own state according to the main tag variation. The digital alarms can be triggered directly by digital tags, especially when these are corresponding to certain field elements like emergency stop buttons, circuit breakers, detectors, and so on. According to the alarm priority for safety of personnel and process integrity, it can be easily implemented a priority–based alarm system. The alarm state can also be recorded over long time periods, providing useful information when process analyze are needed.

Implementing a monitoring system and data processing by PC. This work deals with how is made data acquisition and processing of wastewater treatment processes using a hierarchical architecture and distributed on two levels (Figure 2). The system structures were taken of the following entities:

- parameters – process;
- grouping of processes (node) - dispatcher (server data).

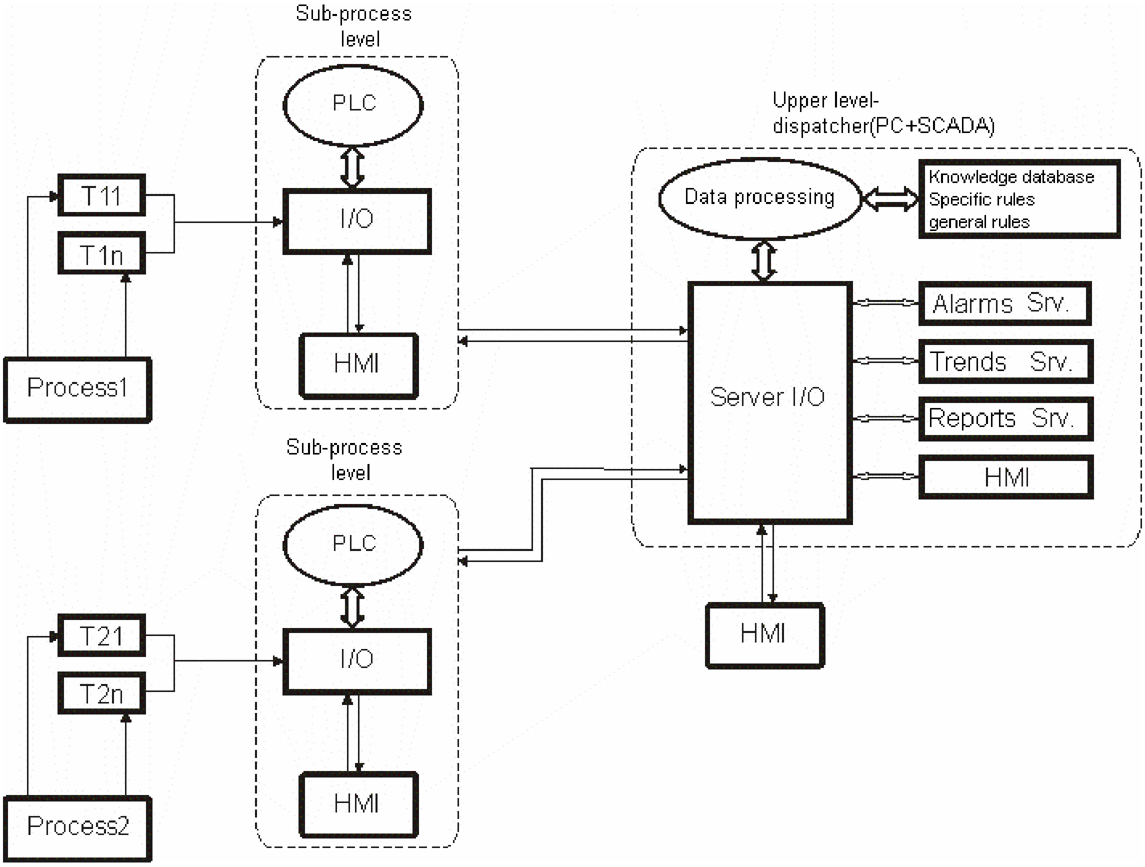

Figure 2. Hierarchically monitoring system distributed on two levels.

Data acquisitions begin at the process level containing elements of converting analogue signals into digital signals and continue with the transmission of data to the supervisor level. The lower level (process) is composed of several PLC (connected to the Internet via a secure VPN networks) and HMI with local monitoring role. Communications components provides a physical means of connection between components, as follows: VPN network deployed on the Internet must be compatible with IP (Internet Protocol), VPN servers must have real and static IP address and VPN clients can have private address IP. For issuing of a virtual private network is required Internet connection (DSL, GPRS, 3G, etc.) in every field point (process) and the command centre, access to data have been made following authentication, through techniques type encrypted tunnel (tunneling), made in the public network. Level dispatching is achieved around a computer (PC) supervisory control, connected to the Internet, which communicates with elements of the acquisition process through secure network (VPN). Dispatcher computer (database server) is running a SCADA application server, which allows you to view information related to the allocated level. This function is available on other computers connected to the Internet through the Web client SCADA or SCADA Internet client. Availability/diversity Internet programs allowing with minimal programming effort the access from distance to automated processes, with the methodology presented.

Depending on the results obtained from processing data provided by various system equipments, these components can initiate various physical operations such as commanding drive and automation components. In the same category are the communications programs too, that connects the system hardware. One of the most important components of SCADA system is a management system that provides database support for real time processing first and second record this data for further analysis.

Conclusions. This work highlights the main advantages of using PCs in the supervision and control systems for wastewater treatment processes.

These offer the opportunity to know the status process to do the changes in process operation from a distance in real time and even reprogram on-line the elements of command and local control (PLC), without the presence on-site of service personnel. Using the PC it is possible to collect a larger amount of data in less time and with minimal error rate. It also offers high flexibility in managing and analyzing the evolution in time of the process, by making automatic graphs and reports. Not least important advantage is the reduced operating costs.

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