Automation and Management Using Intelligent Instrumentation and Field Networks in the Water Treatment Process Automation

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Abstract: – The planet water resources and their respective treatment and distribution processes have also been studied in researches destined to the development of new technologies and automation methodologies to improve the efficacy of control and management systems. This article presents a new water treatment management systemic proposal based on the current scientific and technological advances of intelligent instrumentation and fields network. So, the expectation is to contribute to the operational improvement of water treatment systems, since a more powerful automation platform will enable to implement stricter and more efficient control algorithms.

Key-Words: Automation, Management, Environmental Sanitation, Intelligent Instrumentation, Network

1. Introduction

1.1 Need of a Better Management of Water Resources

Population increase and economy development have significantly increased the demand nature's resources. It is notorious and evident that the concerns about water, or the lack of water, are among the challenges of this millennium. Water is also the main transmission vector of infectious diseases. Among environmental sanitation premises, water supply systems are the ones which cause the greatest impact on the reduction of infectious diseases. Thus, it is fundamental to properly equate the expansion and the operation of water supply systems in the cities, in order to meet the population demand and to supply a high-quality and low-cost product [1].

1.2 Automation as Improvement Tool to Manage Water Systems

Water supply system companies, either in the developed countries or in the developing countries, have an urgent need of improving their operational results due to the new needs imposed by civil and governmental society. Thus, thanks to the advances in electronic engineering in the last decades, it was possible to develop computing systems and sophisticated equipments destined to the water supply systems and sanitary sewage automation. Automation arises as a powerful tool to improve sanitation management, because as well as improving the process quality, it enables methodological collection of the data in an integrated and hierarchized way. Figure 1. exemplifies sanitation cycle, illustrating every stage of the process.

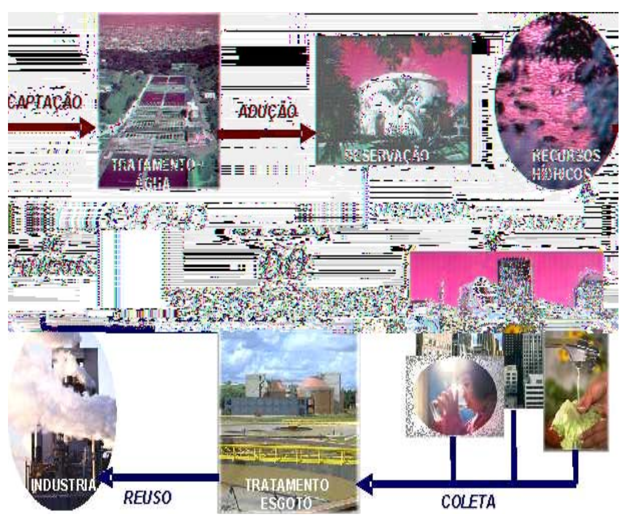

Figure 1. Sanitation Cycle - Source: Water Supply System Company of the State of São Paulo – Sabesp (2005)

2. Intelligent Sensing

Intelligent sensor is the term to designate the physical quantities evaluation measurement system that generally uses a digital computer (or a system with similar architecture) for the entire (or almost entire) processing of the signal and information. The intelligent instrument, after measuring a quantity, performs digital processing to refine the data, that is, filtering, average, linearization, automatic calibration and self-evaluation. So, it is possible to define [2] [3] [4] [5] [6] intelligent instrumentation as the set of techniques and devices used to observe, measure, register physical phenomena and perform actions with more reliability, with connectivity with other equipment and devices, and able to manipulate the quantities observed, aiming at its analysis and processing. Figure 2 shows the frequency measurement of a sine-shaped waveform by an intelligent instrument. It is possible to observe that in the sensor output, the information previously collected becomes data, and there is more immunity to noises during transmission.

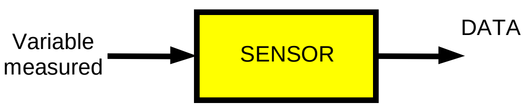

Figure 2 Illustration of Measurement with Intelligent Instrument.

3. Fields Network

In the definition by Instrument Society of America - ISA [2] "fieldbus is a serial, digital, bidirectional, shared-access communication line to interconnect automation primary devices. It includes transmitters/sensors, actuators and other simple devices, with local processing capacity, installed in the field area with control and automation devices of immediately superior level". Institute of Electrical and Electronics Engineers - IEEE presents it as a "bus for general interconnection of simple devices, used in instrumentation, process control and industrial automation".

Fieldbus is a local network designed to work at the lowest hierarchic level in the systems, and one of its purposes is to enable communication between system components from any manufacturer. It is observed that the several models of open protocol field network have different features which may make them more or not so much adequate to a specific application. Therefore, the engineer in charge has the mission to decide which communication protocol is compatible with his installation, that is, which one gives him more flexibility and interoperability so that the instrument of a determinate manufacturer may be replaced with the instrument of another one without any disturbs. The choice of a certain type of network depends fundamentally on the control chains complexity level and on the type of such devices. Industrial networks are qualified according to the type of equipment to which they are connected and the kind of data they carry. Data can be bits, bytes or blocks. Networks with data in bits, or sensorbus, transfer discrete signals containing mere ON/OFF conditions. Networks
with data in byte, or devicebus, may have discrete and/or analogical packages of information, and the networks with data in blocks, or fieldbus, are able to transfer information packages of variable sizes. Figure 3 illustrates the types of network and the forms of data transmission.

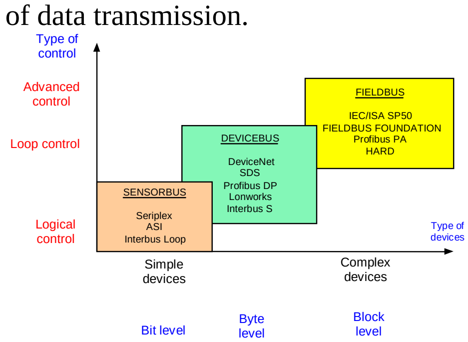

Figure 3. Application Domain of the Types of Network – Source: Smar (1998)

3.1 IEEE 1451 Standard for the Interface of Intelligent Sensors and Actuators

When attempting to interface the intelligent transducer with the several types of existing networks and protocols, IEEE, by means of IEEE P1451 standard, has published a series of standards composed by several parts. Its purpose is to make easier the task of creating solutions based in the existent network technologies, as well as creating standardized connections with the intelligent devices and common software architecture. This standard defines how sensors and actuators can be directly connected to a control network, including Ethernet. The main function of IEEE P1451 standard is to define the communication standard for hardware-independent intelligent transducers. The parts of

IEEE P1451 standard are summarized in figures 4 and 5 [8] [9] of this article.

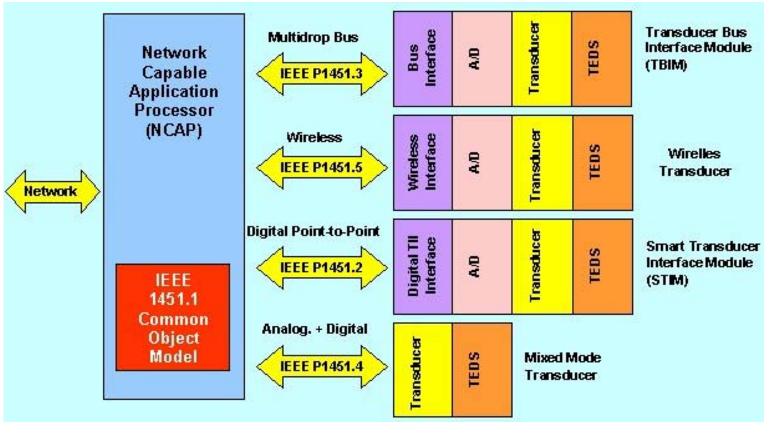

Figure 4. Illustration of the Options of Interfaces of Intelligent Sensors and Actuators –IEEE 1451 Standard - Source: IEEE (2006)

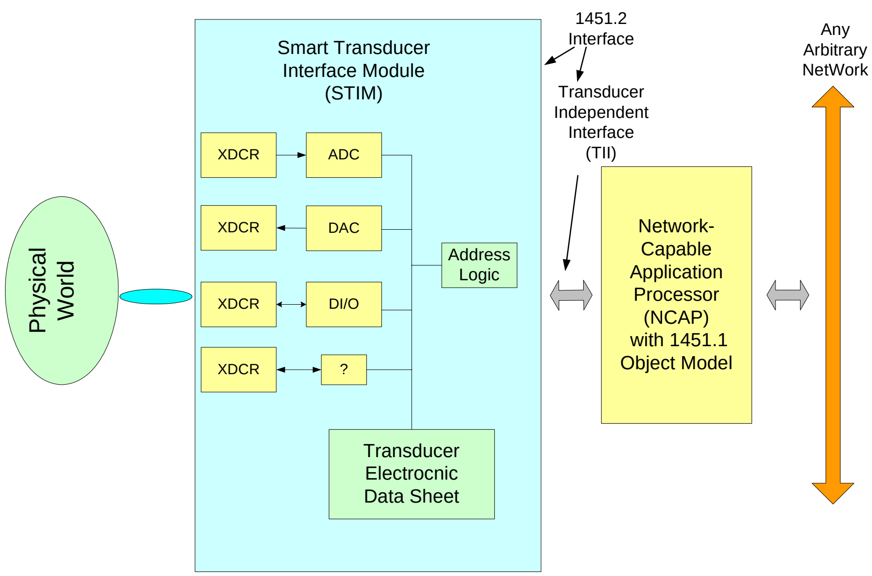

Figure 5. IEEE 1451 Standard Architecture - Source: IEEE (2006)

4. Typical Water Treatment Stations Control Algorithm

Water treatment is made up of several stages, represented by specific units, where physical or chemical processes take place. Such units require a high level of efficiency and accuracy and, above all, a management system which contributes to improvement operations and provides resources for the decision making. Figure 6 illustrates a general diagram about water treatment, where the stages that compose this process are summarized.

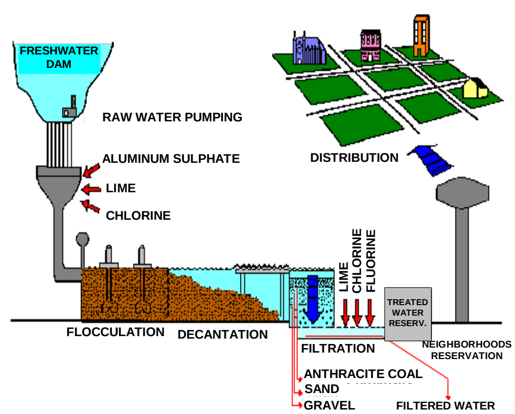

Figure 6. General Diagram of a Water Treatment Station. Source: Water University (2006)

In several countries, most of the water treatment stations are operated and controlled by human intervention twenty-four hours a day. In Brazil, generally Ministry of Health or regulatory agencies establish the rules for the water treatment and supervision. Ordinance 518/2004 by Ministry of Health [11] determines that the water produced and distributed to human consumption must be monitored in order to assure the potability and the quality standards established.
This instrument defines the minimum amount of samples and the frequency of the collections, as well as the parameters and limits established to assure water potability for human consumption. Some samples to control variables are collected at least every two hours, generally in the process output. The samples for the control of other variables required in the process are collected at higher time intervals. All of the results of the laboratory analysis are compiled in monthly reports and made available to the surveillance body. Since water treatment processes are manually operated, the operators are the people who make the collections, the analysis and also eventual corrections in the system.
Due to economic matters and to the lack of reliability of the field instruments, when employed with conventional automation in great distances such as in the medium and big sized water treatment systems, in Brazil, most of the sanitation companies control the different stages of the process also manually. Since water treatment companies are worried about the quality of the services provided, it is perfectly natural that the operators keep the dosage coagulant above the specified value for safety reasons. However, additions of more than 1,0 mg/L in the aluminum sulphate optimal dosage, in medium and big sized stations, may represent a 10% increase in the consumption of this product, or approximately one ton per day, besides the corresponding increase in the lime dosage. This reflects a significant raise in the final cost of water. Hence, non-automated water treatment stations, despite the operators' devotion, are subjected to all of the problems inherent to manual operation, such as: slow response time, quality variability, vulnerability to external factors, raw material waste in the dosage, manual report generation, and lack of anticipation skills to correct deviations in the process.
According to the comments in this chapter, variable analysis for corrections and changes are performed in the end of the process, in agreement with Ministry of Health resolution. However, this kind of procedure delays the responses on the part of the system and lots of fluctuation in the process output. So, many water treatment companies would rather perform such actions manually and, when automated, they use conventional instrumentation in every stage of the system. Figure 7 illustrates in a diagram the manual work in all of the stages during the process [13].

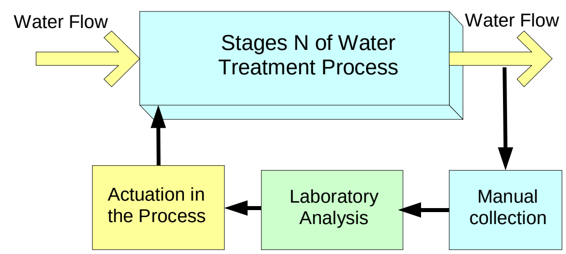

Figure 7. Schematic Representation of Manual Work in Every Stage of the Process in Typical ETA

Water treatment processes cycles are daily performed in different intervals, that is, sometimes variable control is performed at the end of the process and other times it is performed during several stages of the process. Controlled variables in the end of the process aim at fulfilling the resolutions of the surveillance body.

5. Proposal of Hardware Architecture of an Automated ETA With Intelligent Instrumentation (AETII)

The architecture proposed to water treatment stations in this article is made up by intelligent instruments interconnected to a fieldbus. In this architecture, the instruments transmit the process information by means of data bus, that is, information transmitted by the intelligent sensor is data. [13]. This proposal will enable every sensors and actuators to communicate digitally, and also transmit data to the management level, by means of field network, control networks and corporative networks, interconnected in a hierarchic way. Figure 8 represents a hardware architecture proposal using intelligent instruments and fields network in an automated ETA with intelligent instrumentation (AETAII)

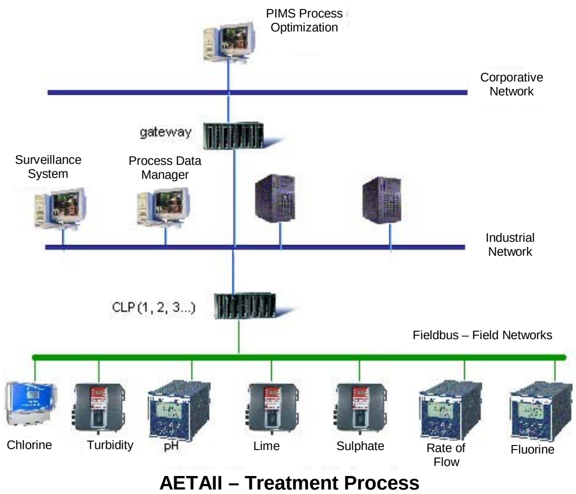

Figure 8. Illustration of Hardware Architecture Proposal Using Intelligent Instrumentation and Fields Network

5.1 AETAII Automation Algorithm

This hardware architecture proposal will enable, among other events, the implementation of more elaborated control algorithms. The objective of the proposed automation algorithm is, besides replacing manual control, to manage resources and administrative decisions. With the proposed algorithm, execution cycle is continuous, so, it is possible to act and to monitor simultaneously in many more points in a fast, accurate and economic way. Figure 9 illustrates the new scheme for the control algorithm correction in all stages of the process of Automating Water Treatment Station with Intelligent Instrumentation (AETAII).

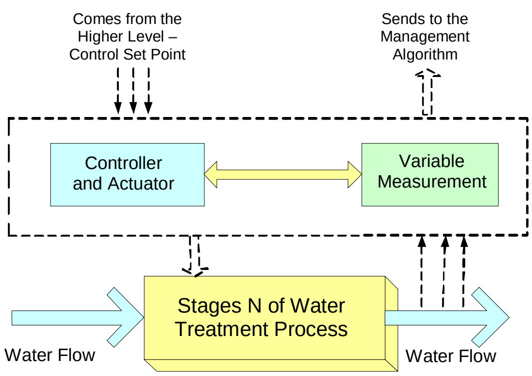

Figure 9. Illustration of the Proposal of Control Variables of Every Stage of the Process in AETAII

Figure 9 shows that the process variables are measured in every stage and the information is processed by the controller who receives the management algorithm set points. It is observed that the information about the variables is also sent to the management algorithm [13].

5.2 AETAII Management System Proposal

This article presents and describes some administrative procedures of a generic AETAII. It is possible to implement, for example, chemical products storage and acquisition administrative procedure. This acquisition can be planned in real time with suppliers by means of publication on the web, because all of the process data are available in the corporative network and stored in the database of the PIMS – Process Information Management Systems. It is possible to effect the automatic calculation of the daily consumption of chemical products, to obtain the current stock level, to automatically control input and output of the lots and loads to return and to receive, as well as the automatic emission of the pertinent report. So, unnecessary acquisition and storage of the inputs are avoided, which reduces costs. Variables such as level, concentration and weight of aluminum sulphate, fluorine and lima tanks, number of existing containers, suppliers invoices and product weight are fundamental to the establishment of this kind of procedure that will certainly be stricter and more efficient in relation to the processes manually operated or with conventional instrumentation automation. Another possible procedure is the elaboration of a historic base to improve management and control algorithms. Most of the process control variables are automatically monitored and transmitted to the corporative system database. Thus, it is possible to generate automatically the water treatment process algorithm history for subsequent evaluation and elaboration of mathematical models to its improvement.

Another possible administrative procedure is the maintenance management. The integration of data on equipment maintenance to the operation control system is extremely important to the effectiveness of the water treatment process. Information about equipment operational conditions, situation of the scheduled and pending corrective maintenance, preventive maintenance schedules with or without equipment paralyzing, characteristics and equipment operation parameters can provide resources to properly manage AETAII. Figure 10 presents an illustration of the management administrative model proposed in this article.

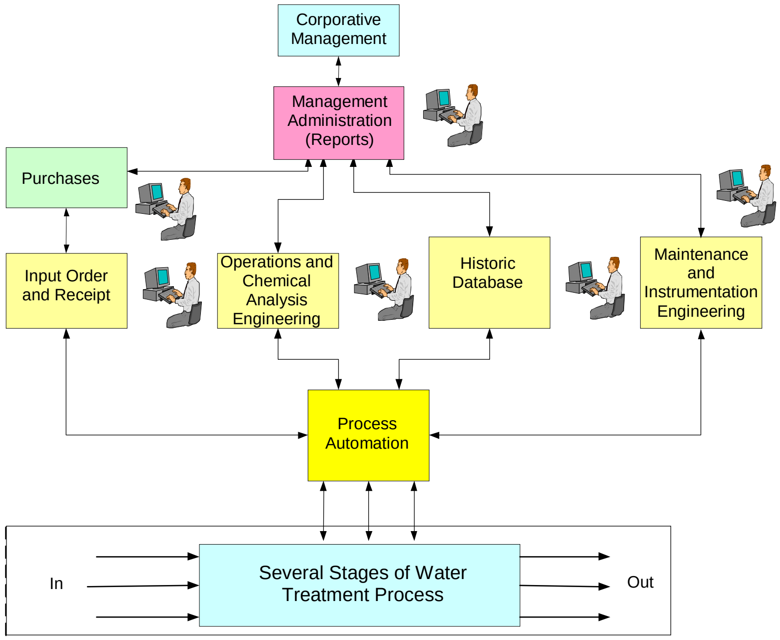

Figure 10. Illustration of Generic AETAII Management Model

6. Conclusions and Future researches

One of the first benefits of the proposed architecture is the initial reduction of interconnection and hardware cables, enabling that only the necessary to start the operation is acquired. So, the instruments become more important in this process, since they become capable of performing self-diagnosis, signal compensation processing, filtering and linearization.

AETAII proposal primordial functions are to generate reports, graphs and information in a more rational and scientific way, and to provide the elaboration of an administrative management model which contributes to the operation of the water treatment process.

Management supported in rational and scientific databases leads to a significant increases of productivity, to a greater reliability of the water treatment process, to the improvement in the quality rates and to the efficiency in terms of power supply. This reflects in revenue increase, production increase and minimization of operation and production costs, mainly in medium and big sized water treatment stations, where thousands of registrations of data are generated everyday.

To sum up, the conclusion is that AETAII brings numberless technical and economic benefits as compared to manual operation and automation of Water Treatment Station with Conventional Instrumentation - AETAIC. This new topology proposed to sanitation sector will contribute to the improvement of instrumentation and, consequently, of automation. Automation, with the new concepts presented in this article arises as a powerful tool in sanitation management and water resources. This article also proposes that new research initiatives on sanitation management of water resources and environment with the use of automation are developed.

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