Implementation of Environmental Monitoring System with PLC and SCADA

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Abstract-- Process measurement and control systems are used in many industrial sectors in order to achieve production improvement, process optimization and accuracy of measurements. In this paper we propose an innovative and tested system that monitors and controls the quality of surface, underground and sea waters. Developed under the use of PLC and SCADA technologies, it is an advanced way to provide prompt and reliable information and an essential instrument for public services, local government organizations, scientific bodies and private companies that manage, control and/or utilize any form of water resources, such as lakes and catchments areas, rivers or torrents, sea and underground waters. The system monitors environmental, hydrological and meteorological conditions in real time with a wireless communication system for instant update and prompt forecast. Consists of a local monitoring station that reside in specific point of interest, which host several sensors for measuring water quality and meteorological parameters, and a data collection central station that collects sensor measurements, stores them persistently, enables users to visualize them, and finally, set and receive alarms when certain measurements exceed some predefined limits. The system is the core of an intelligent system for monitoring and predicting the quality of waters that will be used by the authorities for protecting public health against water pollution.

Index Term-- PLC, SCADA, Environmental supervision

I. INTRODUCTION

In the field of industrial automation the programmable logic controllers, which are known as a PLC (Programmable Logic Controller), presented at the 70s, a major advancement over traditional electromechanical and electronic circuits. The major difference was that in case of PLC, automation circuits were not made with the so-called "hard-wired logic", but with the use of program. This gave the name “programmable logic controller”. Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) are used in many of the automation solutions implemented in most of the industries worldwide. The PLC is used in many applications with great success. A category of these applications are the applications of water resources management.

The right management and monitoring of water resources is nowadays imperative, because the problems of lack of water and of poor quality are increasing continuously. The present article deals with the development of a SCADA application to be used in the supervision of an independent platform, wireless telematic network, consisting of a central station and a floating network of telematic stations located in the water. Using detectors that are installed at onsite measuring stations, the system can wirelessly transmit to the Control Centre plenty of information in real time, which can contribute to critical decision-making and valuable conclusions for reliable short-term forecast. The information is processed immediately at the Control Centre through the advanced environment of the Supervisory Control and Data Acquisition (SCADA) system; results are printed out as reports or alarms are used when limits are exceeded. A database stores a history of measurements and data for analysis and comparison that can lead to forecast and drawing of general environmental and scientific conclusions. To mention some of the unique features of the system: it can record meteorological data; it enables the addition of optional measurement parameters depending on the needs of the installation; it can interface with similar, vicinal networks of environmental control to enable real-time surveillance view across a region. In addition, the system can set levels of access to permit or forbid access to specified unauthorized users and integrates a function of publishing real-time measurements on the Internet.

A. Programmable Logic Controller

Programmable Logical Controllers are computer-type devices used to control equipment in an industrial facility. Are used to control machines and processes where required to be automatic functions: in the industry and in buildings, in shipping, in major public or private sector (tunnels, power plants, mines, wastewater treatment plants), the control traffic, airport lighting, lift systems and dozens of other fields of applications. A PLC is a device with a CPU (Central Processing Unit) used to control the inputs and the outputs of the system (Fig. 1). It has storage memory for program instructions and specialized functions such as Timers, Counters, Arithmetics and built in Regulators. The CPU’s OS Operating System defines the internal device’s operating functions (e.g. activating interrupts) (Fig. 2).

The control program is the program stored within the PLC’s memory that instructs the PLC in which way to control a selected system [1] (Fig. 2). The use of a PLC so as to provide the wiring connections between system devices is named soft-wiring. The soft-wiring advantage provided by programmable
controllers is of a good deal and stresses the importance of the PLCs themselves [2]. Soft-wiring makes it possible to make changes within the system in an easy and low cost manner. If there is a need for a device, which is already controlled by a PLC system, to operate in a different way or to be control using another strategy, all needed to be done is to change the control program. In a traditional system, making this type of change, would involve physically changing the wiring between the devices, which by itself is a costly, time-consuming and error-prone task.

The PLC has many advantages instead of traditional control of automation. A) The wiring of the system usually reduces by 80% compared to conventional relay control system. B) The power consumption is greatly reduced as PLC consumes much less power. C) The PLC self diagnostic functions enable easy and fast trouble shooting of the system. D) Modification of control sequence or application can easily be done by programming through the console or computer software without changing of I/O wiring, if no additional Input or Output devices are required. E) In PLC system spare parts for relay and hardware timers are greatly reduced as compared to conventional control panel. F) The machine cycle time is improved tremendously due to the speed of PLC operation is a matter of milliseconds. Thus, productivity increases. G) It cost much less compared to conventional system in situations when the number of I/Os is very large and control functions are complex. H) The reliability of the PLC is higher than the mechanical relays and timers. I) An immediate print out of the PLC program can be done in minutes. Therefore, hardcopy of documentation can be easily maintained [3].

B. Supervisory Control and Data Acquisition

The supervisory control and data acquisition (Supervisory Control and Data Acquisition) represent the new way to monitor and control a plant or process (Fig. 3). The main purpose of a SCADA system is to display all the equipment in real time from a central point, with all the information to the operator through a GUI. Also, the process control is achieved easily and with full knowledge of what is happening in production. Finally, these systems can store information and data, allowing for subsequent processing.

The connection of a SCADA system with the production is the communication with the PLC, which is responsible for the control of machines, through channels like Ethernet, OPC, RS485. In this way, exchange data and information on the status of the equipment and the procedure of the production process in real time. The status of an engine, a valve, the value of a counter, errors and events, the entire system, can be monitored from a computer screen. In particular, a SCADA consists of a server that manages the monitoring, recording and processing of errors and events that require attention. They also

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Fig. 1. PLC structure

Fig. 2. PLC controlled system

Fig. 3. SCADA system
incorporate trend servers to display graphs critical sizes. Also, modern SCADA systems have connectivity with different type of databases for recording and retrieval of data. This function collects, stores, categorizes, data files and creates reports. This helps in the processing of production data, and exporting reliable conclusions about the quality of the final product, and for any corrections or procedures required for quality assurance and control production costs. Taking advantage of an integrated SCADA, it is obvious that it can boost the production process giving the operator all the information needed for the process. The monitoring of equipment is easier than ever, control and operator intervention is more immediate than ever. The store of critical parameters, statistics production, and export reports are tools of quality controllers for a good quality product.

II. STATE OF THE ART

A number of examples are available in the literature, covering a wide range of applications. The researchers have dealt with the introduction of SCADA systems in different industrial applications, ranging from electrical networks supervision to the pharmaceutical and manufacturing industry. Soetedor et al. [4] present an implementation of Web-SCADA on the hybrid wind-PV power system. Using a web browser electrical parameters such as current, voltage, power and environment parameters such as wind speed, solar irradiation, and PV temperature are monitored remotely via Internet. The SCADA system allows the user to control the hybrid power system remotely [4]. PLC is using also in Building Automation Systems. The authors in [5] used WinCC software in order to making Building Automation System projects. In [6] are described an autonomous and intelligent building systems with redundancy software. Koever-Dorco [7] describes a SCADA system created in common programming language with components and options for the visualization of measurement data. As the primary means for the design of SCADA system was used Java programming language, PLC device and OPC libraries that have been applied in the programming environment Eclipse. In the field of environment are also many implementations with PLC and SCADA systems. Using specified PLC and HMI, it was implemented a reliable automated system, which produces about 120 KWH of green energy, 24 hours a day, 7 days per week from Butuza et. al. in [8]. The system was developed, tested and commissioned at ZANOAGA Drinking Water Treatment Plant and the owner is APASERV VALEA JIULUI [8]. The environment includes the atmosphere, the soil and most importantly the water. By the term “water”, we mean in general the aquatic resources, either surface waters (e.g. lakes, tanks, rivers, torrents, seas), or underground aquatic volumes [9]. In the technologically advanced countries, particularly in the USA and the countries of Western Europe, the need for monitoring the parameters related with qualitative environmental characteristics and particular with the quality of water, has been recognized for a long time. To this aim, several programs of automatic measurement of qualitative characteristics and analyses of results have been installed and placed in operation [10]. S. Dana et al. provide a platform to remotely monitor and control PLC-based processes over TCP/IP or by using the GSM network. The platform is built using industry-standard off-the-shelf PLCs. Integrated with each PLC are communication processors that can be used for connectivity to the network and to a GSM modem [13]. Silva et al describe the development of a monitoring system that involves small plastic buoys/moorings with temperature and salinity probes, signal emitter/receptor devices, and Programmable Logic Controller (PLC) with wireless communication. It is an cheap and efficient water quality monitoring system with meaningful time series that can be statistically treated to allow predictions of water quality changes [14].

III. SYSTEM ARCHITECTURE

The Andromeda Water Monitoring Network is an innovative, platform independent, wireless telematic network consisting of a central station and a floating network of telematic stations located in the water (Figure 4). The Andromeda network sensors are plunged into Thermaikos Gulf of Thessaloniki that collects aquatic numeric data concerning sea water [12].

![Architecture of the Andromeda network](image1)

After sensor readings are collected they are transmitted to a main station for processing and storage. The network consists of (a) several Local monitoring Stations (LMSs) which record and transmit aquatic data to the main station and (b), the Main station (MS), which initiates the communication process with all LMSs and stores the data in the database for future processing. The floating local stations collect all hydrospecific and air indices like water ph, water temperature, dissolved oxygen, conductivity, turbidity, chloride, nitrate and ammonium ions, chlorophyll, direction and air speed, air temperature and humidity, sunlight, rainfall e.t.c. The sensors come from various international vendors with RS232 and analogue output ports (Figure 5) [12].

![Connecting sensors with the central unit of the Local Station](image2)
The core of the LSM is the central unit of collection and mission of data. The central unit includes Field Points of National Instruments, which is a PLC device (Field Point 2000) with suitably adapted cards for input and output (Fig. 6). The complex programming of central unit supports Real Time measurements as well as the bidirectional (two way) communication of local stations with the Central Station of Data Collection. Field Point is an integrated system based on a microcontroller. Its characteristics are more or less the same with a PLC but it has certain advantages compared to a PLC. The advantages of Field Point are that a) it operates in Real Time. The Interrupts that are created within are in real time and they do not wait for the code of program to be completely executed. b) It has the ability of executing the entire program or parts of it. It gives results that as a combination and mathematical analyses of data of its input. c) It has an internal "hard disk" (persistent secondary storage) for storing the input data. d) It has a TCP/IP protocol so that it can be connected and communicate with any TCP/IP device (e.g. a PC) with a very simple way and e) It can be extended very easily [12].

Furthermore, the user can redefine the exact, predefined times for data retrieval from the measurement stations. Additionally the user can retrieve data from the stations on demand.

### Table I

**Daily Meteorological Data from one LMS 14/05/2014**

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE (°C)</th>
<th>HUMIDITY (%RH)</th>
<th>SOLAR RAD. (W/m²)</th>
<th>WIND SPEED (miles/h)</th>
<th>WIND DIRECTION (°)</th>
<th>RAINFALL (mm)</th>
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<tr>
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<td>87.13</td>
<td>0</td>
<td>2.44</td>
<td>143.24</td>
<td>0</td>
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<td>21.18</td>
<td>88.43</td>
<td>0</td>
<td>1.92</td>
<td>-59.7</td>
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<td>3.76</td>
<td>14.25</td>
<td>0</td>
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<tr>
<td>8:00</td>
<td>22.39</td>
<td>92.16</td>
<td>4.02</td>
<td>1.01</td>
<td>261.28</td>
<td>0.44</td>
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<td>93.07</td>
<td>1.02</td>
<td>3.88</td>
<td>217.29</td>
<td>0</td>
</tr>
<tr>
<td>12:00</td>
<td>22.46</td>
<td>93.29</td>
<td>13.43</td>
<td>2.67</td>
<td>157.05</td>
<td>1.32</td>
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<tr>
<td>14:00</td>
<td>23.73</td>
<td>90.52</td>
<td>25.89</td>
<td>2.32</td>
<td>156.6</td>
<td>0.88</td>
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<tr>
<td>16:00</td>
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<td>86.22</td>
<td>6.23</td>
<td>2.58</td>
<td>54.04</td>
<td>1.54</td>
</tr>
<tr>
<td>18:00</td>
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<td>3.7</td>
<td>43.73</td>
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</tr>
<tr>
<td>20:00</td>
<td>25.07</td>
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<td>309.05</td>
<td>0.73</td>
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<td>0.48</td>
<td>306</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table II

**Daily Hydrologic Data from one LMS 14/05/2014**

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE (°C)</th>
<th>PH UNITS</th>
<th>COND. (µS/cm)</th>
<th>SALINITY (ppt)</th>
<th>OZ% (Sat)</th>
<th>OZ (mg/l)</th>
<th>DEPTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6.99</td>
<td>0.322</td>
<td>0.16</td>
<td>20.2</td>
<td>1.51</td>
<td>0.15</td>
</tr>
<tr>
<td>2:00</td>
<td>20.55</td>
<td>6.99</td>
<td>0.322</td>
<td>0.16</td>
<td>19.1</td>
<td>1.43</td>
<td>0.16</td>
</tr>
<tr>
<td>4:00</td>
<td>20.49</td>
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<td>0.16</td>
<td>20.9</td>
<td>1.57</td>
<td>0.16</td>
</tr>
<tr>
<td>6:00</td>
<td>20.49</td>
<td>7</td>
<td>0.323</td>
<td>0.16</td>
<td>21.1</td>
<td>1.58</td>
<td>0.15</td>
</tr>
<tr>
<td>8:00</td>
<td>20.51</td>
<td>6.99</td>
<td>0.321</td>
<td>0.16</td>
<td>20.2</td>
<td>1.51</td>
<td>0.15</td>
</tr>
<tr>
<td>10:00</td>
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<td>6.99</td>
<td>0.324</td>
<td>0.16</td>
<td>21.6</td>
<td>1.62</td>
<td>0.15</td>
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<tr>
<td>12:00</td>
<td>20.78</td>
<td>7.02</td>
<td>0.326</td>
<td>0.16</td>
<td>21.9</td>
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<td>0.15</td>
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<tr>
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<td>7.03</td>
<td>0.323</td>
<td>0.16</td>
<td>30.8</td>
<td>2.28</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Andromeda is an innovative open interoperable platform which is able to configure any type of sensors available by the industry while at the same time it may be expanded with numerous additional controllers. Furthermore Andromeda is designed to use sophisticated prediction systems in case of disaster events.

IV. CONCLUSION AND FUTURE WORK

From the above discussion it is evident that when it is possible for the authorities or organizations that are involved with the management of aquatic resources to monitor the quantitative and qualitative parameters that are related to the aquatic environment, then they will be able to make conclusions about parameter trends, to predict undesirable situations on time and therefore to take counter-measures in a timely fashion. Furthermore, longer term actions include strategic resource planning for regional growth and development. Therefore, the importance of further developing the system is more than obvious.

With such a system in use an environmental information centre is created that is able to monitor environmental quality parameters in real-time so that pollution spread can be avoided. This network of monitoring stations can be expanded in nationwide network, so that authorities can have both a regional and a nationwide real-time picture of the hydrological and meteorological environment. Without an on-line sensor network, this would be impossible.

Concerning future work is planed to install more such regional networks of environmental control and then integrate all those networks into a single supermonitoring central station. The MS of each network will aggregate measurements of regional stations and will transmit them to the central station.

Furthermore, critical regional alerts will also be transmitted to the central station. Another point for improvement is the possibility for bidirectional communication between the LMSs and the MS. This means that the central unit of the LMS can decide on its own when it is important to transmit measurements to the MS and not wait for the next predefined rendezvous time. In a second phase the liable authorities are informed (since the system functions in real time) so that responsibilities can be traced and environmental pollution can be prevented (intervening in time and region that becomes known from the system) either this emanates from the interior of the country or from abroad (e.g. cross-border rivers).

The present sensor network will become the core of an intelligent decision support system that is currently under development. This system will provide added value services to the authorities in the “decision-making” process in the battle against the pollution of the environment [11].

The intelligent decision support system will be able to determine when the environmental parameters exceed certain “pollution” limits, which are specified either by the authorities or by environmental scientists, and issue appropriate alerts. The difference of this intelligent system with the current system is that the former will be able to check complex conjunctive situations using not classical but fuzzy logic. Furthermore, different limits may exist for different uses of the waters (e.g. aquiculture, swimming, etc), so the system must be able to

Fig. 8. Hydrologic and meteorological parameters.
distinguish between those limits and the corresponding alerts for each parameter. Additionally, the intelligent system will be able to predict future values of the environmental parameters, based on the history of the measurements, and to issue early warnings.

REFERENCES


