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A Framework for Building a SCADA System for Beit Lahia Wastwater Pumping Station*

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ABSTRACT: Designers of the New Terminal Pumping Station (NTPS) which is currently being constructed at Beit Lahia have specified precisely the requirements and features of its automation system along with its Supervisory Control And Data Acquisition (SCADA). However, the exact system configurations as well as the number of components or their model are left unspecified in order to provide flexibility for different manufacturer strategies. The aim of this research is to analyze the SCADA system requirements and propose a solution strategy which fulfils the designer specifications while minimizing costs and insuring long term system robustness.

بناء نظام تحكم إشرافي (SCADA) لمحطة ضخ المياه العادمة في مدينة بيت لاهيا

ملخص: الجهة التى صممت محطة ضخ المياه العادمة في مدينة بيت لاهيا قامت بشكل دقيق بتحديد شروط و مواصفات نظام التحكم بالمحطة و كذلك نظام الإشراف المحوسب و إكتساب البيانات (SCADA) الخاص به. و لكن في ذات الوقت ، تركيببة النظام الداخلية و عدد قطعه و شركاتها المصنعة تركت بدون تحديد و ذلك لإعطاء مرونة كافية أمام إحتمالية تطبيق إستراتيجيات شركات متعددة. يهدف هذا البحث لدراسة وتحليل متطلبات نظام ال SCADA و من ثم طرح إستراتيجية مميزة لتنفيذه. لقد حرصنا في التنفيذ على تحقيق المواصفات المطلوبة مع مراعاة تقليل النفقات والتأكيد علي مرونة و متانة النظام.

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1. BACKGROUND

The Beit Lahia wastewater treatment plant (BLWWTP) was constructed in 1976 in the northern part of Gaza Strip. The system was designed as a secondary treatment plant with a capacity of 5,000 m^3/day and to serve a population of 50,000 in the municipality of Jabalia. The treated effluent was simply let out into the sand dunes at the western side of the plant. In the first few years of operations this practice did not cause problems because the effluent quality was good and the sandy soil was able to handle the volume of effluent through natural infiltration. During the past few years the situation escalated. Many communities were provided with sewerage networks and were connected to the BLWWTP. The presently served population is about 180,000 and that includes the municipalities of Jabalia, Beit Lahia, Beit Hanoun, and Um Al Nasir. Consequently, the volume of wastewater inflow to the plant (currently estimated at more than 12,000 m^3/day) has exceeded the plant's treatment capacity by far. The combination of increasing volumes of generated wastewater and insufficient treatment capacity at the BLWWTP has led to deterioration of the effluent quality. The great volumes of poorly treated wastewater have led to clogging effects in the neighboring sand dune areas. The ongoing decrease of the infiltration capacity of the flooded areas and the increasing wastewater volumes have resulted in the formation of enduring ponds and finally a lake [1].

In order to prevent human and ecological disaster in the densely populated Beit Lahia area, the Palestinian Water Authority conducted a "Northern Gaza Emergency Sewage Treatment" (NGEST) project. It targets to drain the existing effluent lake and convey its partly treated effluent to the new wastewater treatment plant site (WWTP). The first phase of that project consists of:

- A terminal pumping station at the site of the existing BLWWTP for target capacity up to year 2015 flow.
- Pressure pipeline (8 Km) to transfer the effluent from BLWWTP and the effluent lake to the infiltration basins of the proposed WWTP location.
- Nine infiltration basins with a total maximum infiltration capacity of 35,600 m3/ day.

Work on this phase has been started two years ago and it is expected to be completed soon. In this paper we aim to present our approach in building the required SCADA system. The rest of this paper is organized as follows;

an overview of SCADA systems is provided in Section 2. The hardware design of the undertaken system is described in Section 3. The software approach and its components are presented in Section 4. Finally in Section 5, results, conclusions, and suggestions for future work are summarized.

2. OVERVIEW OF SCADA

SCADA is not a full control system. However, it focuses on the supervisory level. It is a software package installed on networked computing platforms, like PCs or small dedicated devices which are hardened for industrial environments. SCADA provides a high level layer on top of the Programmable Logic Controllers (PLCs) layer which is positioned over the plant hardware devices. Thus, we have a functionally modular platform in which there are three layers interacting with each other in a hierarchical manner as sketched in Figure 1.

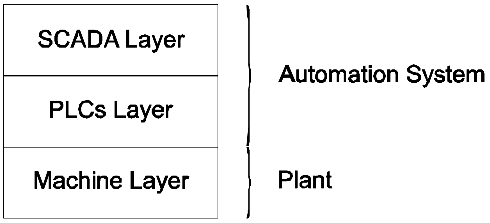


Figure 1. Functional decomposition of an automation system.

SCADA systems are used not only in industrial processes, but also it is used intensively in wastewater applications. In such applications wastewater is often pumped long distances, measured in kilometers, through subsequent pumping stations in order to reach the treatment plant. To deliver optimum results, remote automation locations must be tightly coordinated and a useful Human Machine Interface (HMI) is required. Advances in automation technology have evolved modern SCADA solutions which helped overcoming these challenges while reducing wastewater processing costs and providing an accurate overview of plant operations [3,4].

A typical SCADA system encompasses two software layers the “client layer” and the “data server layer”. The former one caters for human machine interaction while the later layer handles data acquisition and processing (polling controllers, alarm checking, calculations, logging and archiving). These layers may use a shared communication network as illustrated in Figure 2a or they may utilize dedicated independent networks as illustrated in Figure 2b. The first approach insures implementation and maintenance simplicity while the second approach provides a higher bandwidth and a better degree of redundancy. It should be noted that both client layer and data server layers are software components that may be installed in a single workstation as a centralized system, or they may be partitioned on a number of PCs as a distributed system. Many factors influence the strategy used by the system designer. Cost, system complexity, physical size of the plant, information security and redundancy are the dominant factors.

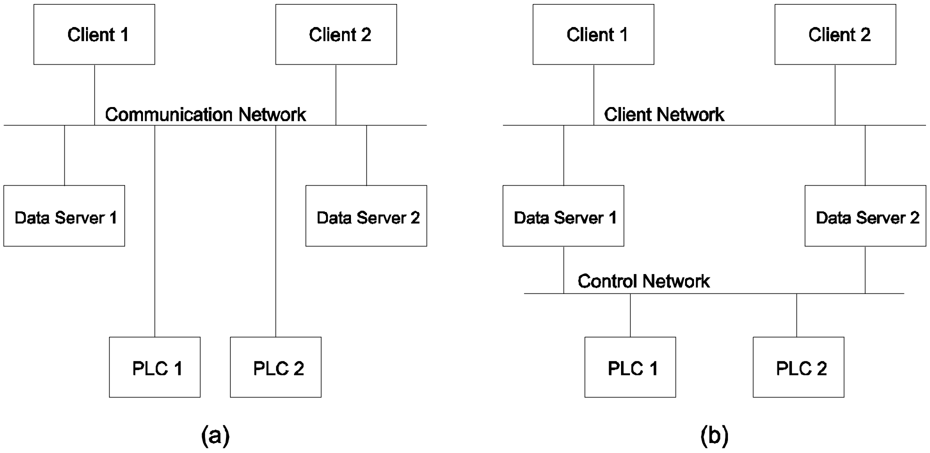


Figure 2. Typical communication schemes.

3. HARDWARE DESIGN

According to project specifications, it is demanded that the system has to be split up in two separate subsystems in order to form a degree of redundancy [2]. Figure 3 has been provided as a general guide line for implementing the SCADA system hardware.

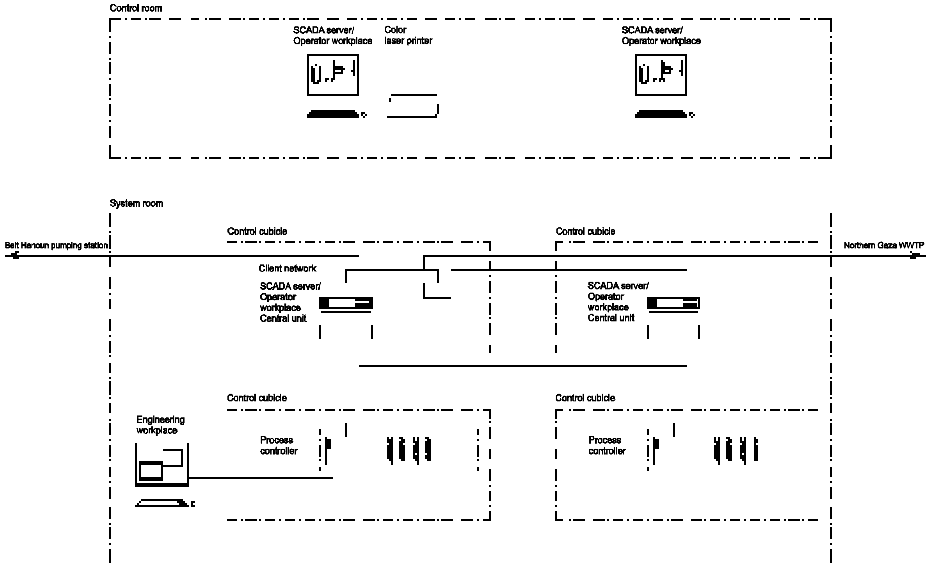


Figure 3. SCADA hardware layout.

It is clear in the figure that the two PLCs which control the two subsystems should be interconnected to allow communication between the subsystems. Moreover, each PLC is recommended to have another interface to form a control network. Issues of PLCs selection and programming are outside the scope of this paper as we are focusing on the top layer of the automation system which is related to the communication network and the operator interface. Hence, it suffices here to indicate that the PLCs have been selected of type Siemens S7-400, CPU414-2. Each unit has a build in PROFBUS DP interface and connected to an Industrial Ethernet TCP/IP interface communication processor (CP 443-1) module. The first interface will be allocated for PLCs communication while the other interface will be utilized to interface PLCs to SCADA servers through a control network based on Industrial Ethernet. It is also understood from the design guidelines in Figure 3 that while there should be another network dedicated for the client layer, local clients are allowed to be installed at the data servers. On the other hand, remote clients at WWTP will be connected through a fiber optic cable and another fiber optic cable should be reserved for future interconnection with Beit Hanoun Pumping Station (PHPS). Similar to what we have done in the control network, we decided to lean on the Industrial Ethernet standard to realize the client network. It should be noted that Industrial Ethernet offers a powerful features with standard IEEE

802.3 and 802.3u. At present it is the number one network in LAN landscape, with a market share of over 80%. Industrial Ethernet is ideal for creation of powerful long distance communication networks. Figure 4 describes the hardware implementation in which we selected Hireschmann Industrial Ethernet switches [5,6,7].

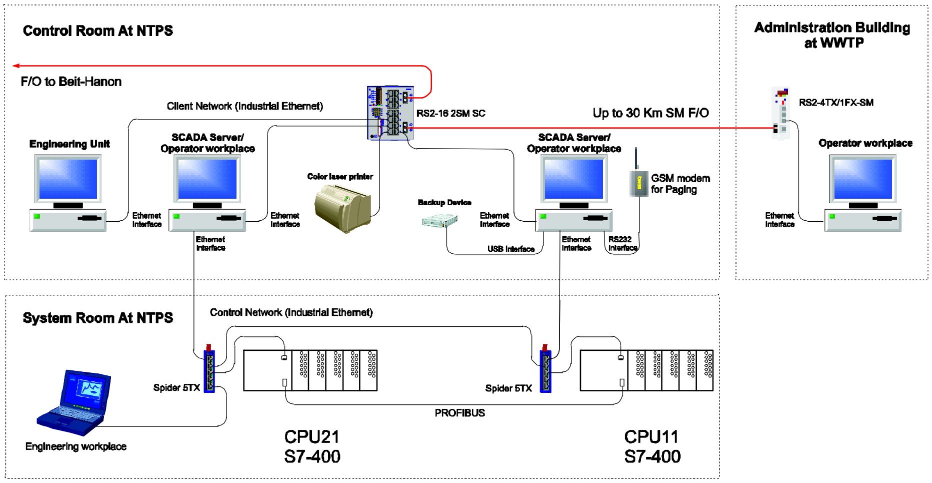


Figure 4. Proposed system implementation.

4. SOFTWARE ARCHITECTURE

There are many software packages in today's Information Technology (IT) market which enables engineers with moderate programming experience to build SCADA applications. WinCC from Siemens, Cimplicity HMI from General Electric, and Lookout from National Instruments are well known examples for efficient commercial SCADA packages. However, professional computer programmers are biased to standard programming languages and tools in building SCADA applications. This lower level programming approach offers them more freedom to configure their project with highly reduced restrictions which are associated to these higher level packages. Moreover, while using standard programming languages allows SCADA developer to put their own character in the final product, the cost of extra programming efforts is fairly compensated by savings in software packages expenditure [8].

In order to build a SCADA application using a standard programming language such as Visual Basic, programmers still need supporting tools such as device drivers and database servers. OPC (OLE for Process Control) is an open standard designed to bridge process control hardware and software applications [9]. Therefore, an OPC server is simply a PLC device driver which enables programmers to communicate with that PLC trough a standard interface. In this project we utilized an OPC from Kepware while we used Microsoft SQL server for the database [10,11]. Using Visual basic and these two standard interfaces to PLCs and Database we built the SCADA server application which handles data archiving, alarm processing, and events logging. It is also required that the SCADA server has to comprise a paging system. This system has to use SMS to alert operators in case alarm events are left unacknowledged for a longer time than an adjustable set delay time. Therefore we created a pager program based on MOD 9001 BENQ GSM/GPRS modem [12,13].

The software components, presented till this point, are all belong to the data server layer of the SCADA. Before proceeding in describing the remaining software components which constitute the client layer, it is helpful now to present Figure 5. This figure provides a good insight and a detailed specification of our layered architecture depicted in Figure 1. The interface standard and communication medium is also indicated in the figure.

One of the client components is the *account manager*. It helps system administrators to manage system users and allocate their groups which have defined read/write access privileges to process parameters. The *HMI component* comprises many displays which are built up from information in the process flow. For example, Figure 6 presents the plant overview display and Figure 7 presents a pump display.

The trending tool allows data to be trended in a specific chart. Real-time and historical trending are possible, although not in the same chart. A chart may contain up to 8 trended parameters and zooming as well as scrolling is provided.

There are three types of events to be logged in the system: The first type is process events such as “pump is switched ON” or “valve is opened”. The second type is alarm events such as “overflow started” or “pump is over heated”. The third type is user events such as “alarm acknowledge” or “parameter modification”. The first two types are registered in the database by the SCADA server while the last type is registered by clients.

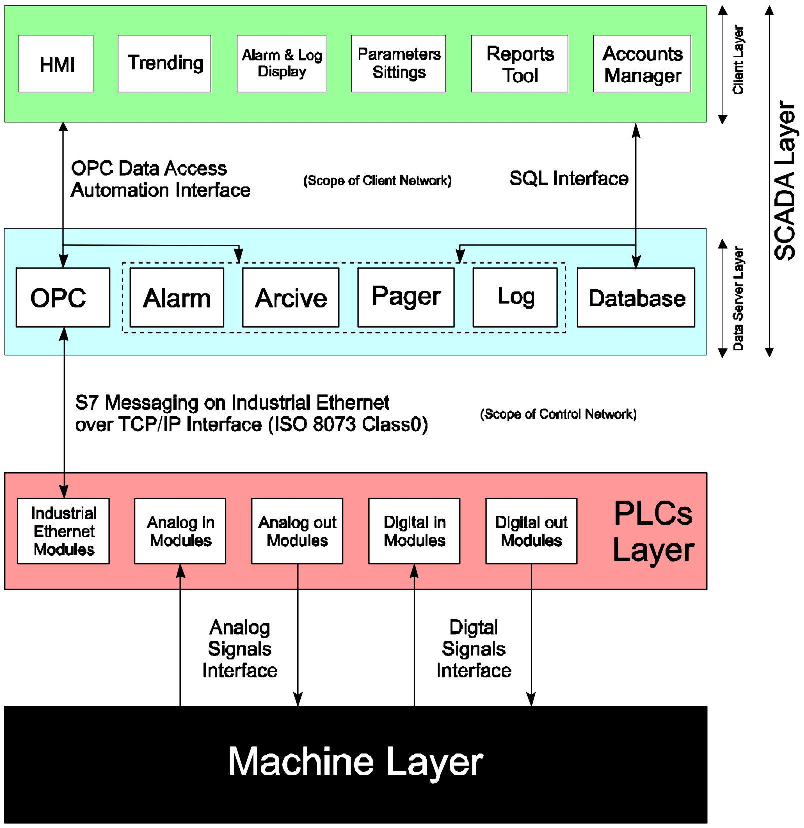


Figure 5. SCADA software components and their layered model.

Since changes in database tables can not trigger interrupt actions in client workplaces, the only apparent way to enable clients update various event lists is the polling technique. However, we went around this problem by reserving a tag in the OPC server to facilitate interrupt capabilities between clients and a data server. Whenever an event occurs, the responsible handling subroutine (whether it belongs to a client or a server) toggles that tag. This action which is configured to trigger an interrupt in all connected clients is utilized to update the *alarm and log display* lists.

The client package includes forms to *adjust system and alarm parameters*. The *reports tool* allows reports to be produced using SQL type queries. Some reports generation and printouts are configured to be event driven actions triggered from a time schedule. Figure 8 shows the client main interface.

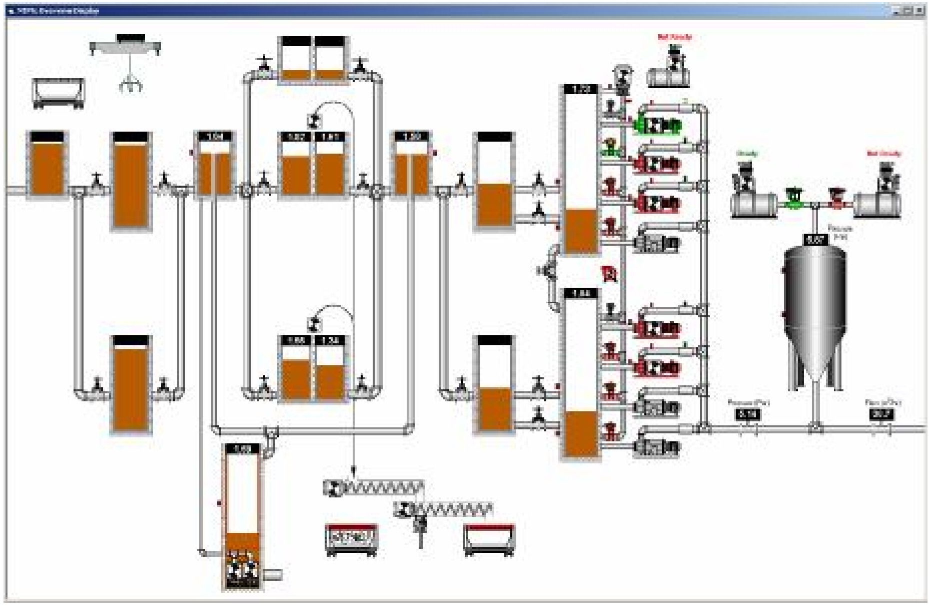
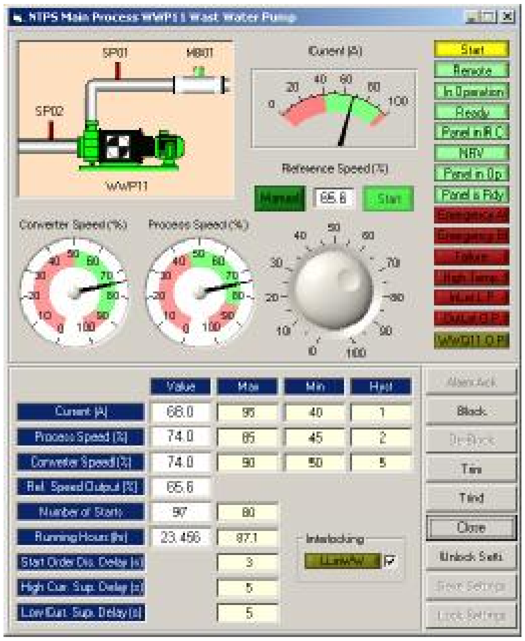


Figure 6. Plant overview display.

5. RESULTS AND CONCLUSIONS

In this paper we presented a framework for building a SCADA system for Beit Lahia Wastewater Pumping Station. The hardware communication medium comprises two independent networks (a control network and a client network) that are based on Industrial Ethernet. The architecture ensures one redundant SCADA server/Operator workplace. The software is built using Visual Basic 6 which guaranties flexibilities necessary to implement and customize the SCADA package as required in the bidding documents. The proposed framework has successfully passed our experimental tests and expected to be installed on the project site soon.

In a future work, we plan to explore the features and capabilities of some commercial SCADA packages and utilize one of them to build an educational wastewater treatment plant. We intend to design and implement its SCADA system and build a PLC simulator to substitute the plant hardware.



	Value	Max	Min	Hyst
Curent (A)	68.0	95	40	1
Process Speed (%)	74.0	85	45	2
Converter Speed (%)	74.0	90	50	5
Ref. Speed Output (%)	65.6			
Number of Starts	97	80		
Running Hours (hr)	23.456	87.1		
Start Order Dis. Delay (s)		3		
High Cur. Sup. Delay (s)		5		
Low Cur. Sup. Delay (s)		5		

Figure 7. A wastewater pump display.

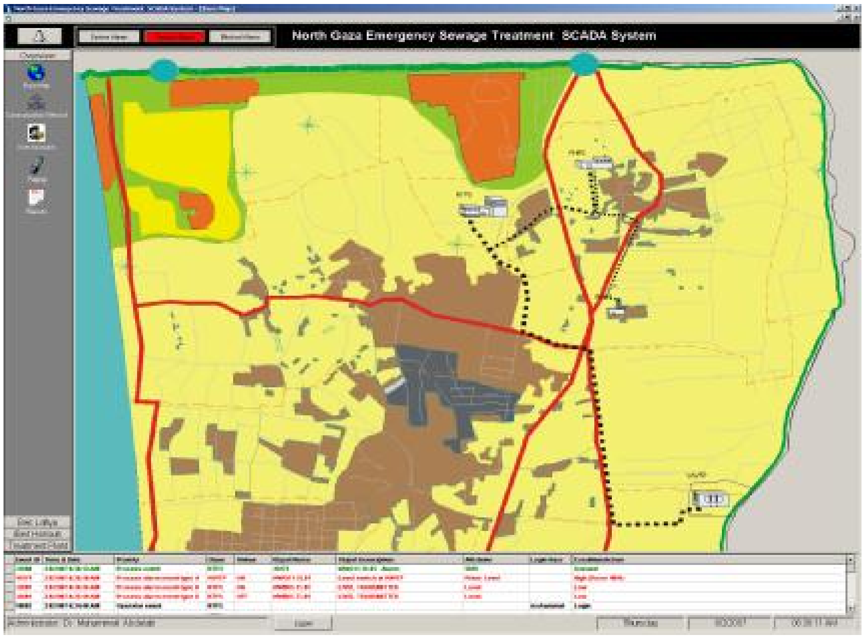

North Gaza Emergency Sewage Treatment SCADA System
Overview
Beit Lahya
Beit Hanoun
Treatment Plant
Administrator: Dr. Mohammad Abdelati
Login

Figure 8. Client main interface.

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