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Communication Technologies for Complex Industrial Systems

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***Abstract*— In case of industrial sites located in isolated geographical areas, access to wired internet connection can be a challenge. This paper presents an evaluation of possible configurations for a remote monitoring and control of a wastewater plant. The plant does not have a public IP and the internet is acquired using a mobile connection on a router directly connected to the plant PLC. Two possible solutions are presented, using a VPN router and through an OPC tunnel.**

***Keywords*— data transmission, GSM communication, SCADA, remote control, VPN tunnel.**

I. Introduction

In today's economic environment, every major producer of goods, like national utility companies from the water or energy sector, oil extraction and processing companies, renewable energy etc., has their production and supply chain geographically situated all over the country, continent or world. This situation shows a necessity for the companies and brings a new problem for the system integrators to solve, the communication between geographically scattered sites.

What started as a simple human to human communication between sites, using telephone lines and later, using the internet for communication between plant managers, evolved in accordance with the new technologies and standard communication protocols, to machine to machine, plant to plant communication and data and information transfer using industrial internet protocols, GSM, GPRS, satellite communication, telecontrol, radio or Wi-Fi.

The new means of communication increase the availability of plant data and allow the implementation of new applications that can reduce the involvement of the human operator, allow direct data integration in ERP or asset management applications, and, by use of mobile application or alarming modules, can raise the speed in which the plants or the dispatcher is informed regarding process operation [1].

Another usage for remote data acquisition is maintenance and data analysis of the plant. This allows remote supervisor applications to analyze information that is acquired from the target plants. The information is analyzed and decisions can be made if human intervention or predictive maintenance is needed. The remote data acquisition is a key requirement for unmanned remote plants, like distributed wind farms, water supply pumps, wastewater pumps, gas supply installations etc.

In case of industrial sites located in isolated geographical areas, access to wired internet connection can be a challenge. While satellite connections are highly expensive, the most accessible solution is represented by GSM/GPRS networks. At the same time, to ensure there are no security breaches, only certain areas of a plant can be accessed remotely. The correlation between requirements from the process control engineer points of view, plant network security, service provider and implementation cost must be taken into consideration in identifying a best solution.

This paper presents a typical case of a plant that must be connected to a remote Decision Support System and evaluates possible interconnection solutions considering there is no current internet connection available. Our objectives are to research potential methods of implementing the communication component of a wastewater plant, and to present and analyze the method applied in our situation that was implemented within the project.

The rest of the paper is structured as follows: section II presents existing technologies and architectures for remote plant connection. Section III describes the plant used as case-study, existing limitations and data connection requirements. Section IV presents two possible connection solutions for accessing remote plant data without the need of a fix IP address. Section V concludes this paper.

II. Available Communication Technologies

A. Previous Related Work

Remote control is the kind most facility technology up to date, as it allows us to do things from a distance, in a short period, and with minimal effort. Combined with the acquisition of production-related information and process state, remote control can help implement the digital enterprise concept at the plant level [2]. This topic has been addressed previously in several research papers.

In [3] the authors present the remote control of a pumping station in the water supply system by using monitoring systems installed in the entire building and assisted by alarm

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sensors which quickly help identifying faults. This leads to an increase in the overall efficiency of the management system.

The link between the station and the operation and maintenance center is established using radio frequency data transmission leveraged by the mobile operators. It is a web-based system, which uses a long-range GSM link and conventional internet transmission to collect data, also in real time of the pumping station systems.

In [4], by using a system made of three microcontrollers, the authors could monitor the waterwheel of a small hydroelectric power station, which is autonomous and located in isolated remote area. For automatic control, a "peak power tracking" algorithm is implemented and its output is sent every 10 seconds via GPRS/ Internet to the monitoring terminal.

Three communication modules are implemented: control, surveillance and communication by using the following protocols: TCP/IP, GPRS, SMS and ZigBee.

A remote monitoring system of a conventional wastewater treatment plant, which was previously manually operated for an energy-saving project is presented in [5]. The focus on the energy savings can be spotted in the section which controls the dissolved oxygen in the context of nitrogen removal. By using automatic controllers, the oxidation process is adjusted through controlling the air flow to the time varying treatment requirements.

A RTU (Remote Terminal Unit) is used for each plant to collect and transmit data via low-speed dedicated modem lines, radio modems in the UHF band, GPRS and/or Ethernet lines. The paper describes the first step in the project development, the setup of the plant monitoring from a management center, and, using a VPN connection, from an authorized client.

With regards to the fuel management spending, there are a lot of published technical documents, which describe experiences on remote technology [6]. At the reactor sites, interim storage facilities, reprocessing or disposal facilities, due to the heavy weight and large size of spent fuel casks, heavy duty handling facilities capable of accommodating at least a truck access are required.

To minimize human interaction remote automation is used for devices, bolt/stud tensioners, robotic manipulators, even though the cask surface is supposed to be within acceptable dose limits to the workers.

Major concerns for remote technology applications are raised especially where human operation and intervention is extremely dangerous or impossible, for example, inside radioactive enclosures [6]. To avoid dangerous situations, like human exposure, the best solution is to implement tele-operations and tele-robotics. However, due to lack of experiences or reliability, this has limited use.

These researches enable the faster adoption of cloud, wireless sensor networks or context-aware approaches at the industrial level. An example of how these technologies have been integrated into industrial applications was presented in [7].

B. Available Technologies

There are several solutions available, adapted to the particularities of each site location. Current routing devices integrate Ethernet, GSM and WiFi connections, and their performance depends mainly on the service provider, so from the applications' point of view the network type is not important. Depending on the allocated budget, the beneficiary can choose between a public or private, static or dynamic IP address. Difference between these determine the technologies that can be used.

A list of available remote connection solutions based on OPC protocol over an Ethernet transmission, according to the IP connection type is presented in Table 1. A public IP or external IP is considered a user's IP that can be directly accessed from the Internet. The opposite of this is a private IP which determines how a device can be accessed inside a network. Because the number of available public IPs is lower than the number of users, some ISPs can provide customers a private IP. Moreover, some ISPs can provide a static IP, meaning an IP that never changes, or dynamic IP, one that may change. Under these considerations, a static or dynamic IP can be either under a public network, thus being reachable, or over a private one, where they can only initiate connections to reach remote locations.

TABLE 1: REMOTE CONNECTION SOLUTIONS

IP type	***Solutions***	***Min. requirements***
Static IP over a public network (Public IP)	Direct OPC server connection	DCOM and firewall settings
	OPC tunnel	OPC server for the PLC protocol
	Remote access application	PC on site, large network bandwidth
Dynamic IP over a public network	VPN connection	Router with VPN client, remote VPN server with public IP
		Router with VPN server and dynDNS
	OPC tunnel	Router with dynDNS OPC server for the PLC protocol
	Remote access application	PC on site, large network bandwidth
Dynamic or Static IP over a private network	VPN connection	Router acting as a VPN client, VPN server with public IP
	OPC tunnel	Cloud application for OPC tunnel connection
	Commercial remote access application	PC on site large network bandwidth

III. PLANT DESCRIPTION

A. Wastewater treatment plant

The production process from the food and drinks domain result in a big quantity of wastewater generated from tanks cleaning, vegetables washing or processing. To control the impact of these residues on the environment, strict regulations must be followed to ensure proper organic levels.

The remote plant referred in this article is an experimental 100L wastewater treatment plant. The plant is a two-phase acid/gas wastewater treatment plant designed following the principle of anaerobic digestion.

The plant has for major components, where the chemical and biological processes occur: the feed area, the acidogenic area, the methanogenic area and the gas handling area. The installation's objective is to process wastewater and pulp waste that results following normal operations in small and medium food and drinks production companies, into biogas that can be captured and used as fuel for heating or electricity generation.

The project developed a small scale cost-effective solution of a wastewater treatment plant to be used by SMEs in the food and drink sector. The technology uses a two-stage anaerobic reactor that combines wastewater with nutrients, under strict pH and temperature control, to ensure proper levels of COD (chemical oxygen demand), Natrium, Phosphor and TSS (total suspended solids) or the production residues. This process results in biogas production that can be reused in the plant energy consumption.

B. Data transmission

The wastewater plant was designed independently of a food processing facility and tests were performed at different locations, in two types of plants (juices and wine) for evaluating its efficiency. Because of this, its control system was completely independent of the local network and of the control system from the installation facility.

The control application allows the monitoring of main process parameters (temperature, pH, tank level, input and output flow) and different levels of control from individual actuator action (pumps or heaters), to starting or stopping individual processes and even fully automatic control.

With the main purpose of minimizing operation costs, the implemented control logic was designed for continuous operation under automatic control based on fuzzy rules. Because of this, wastewater plant monitoring and control can only be done through a local HMI, without continuous operator supervision. The connection to a remote decision support system enables proper evaluation of plant state and performance. Fig. 1 shows the plant's data transmission diagram. Process parameters are collected by a PLC and are sent to a remote SCADA application through a GSM mobile connection.

C. Decision Support System

We designed the DSS as a modular and scalable system that can connect simultaneously to several plants for both concurrent data acquisition (in case of SCADA monitoring, alarm management and FLC trend analysis applications) and individual analysis and optimization.

The focus of the system is on increasing efficiency in data collecting, but the chosen solution also provides the possibility of remote commissioning for fast engineering technical support.

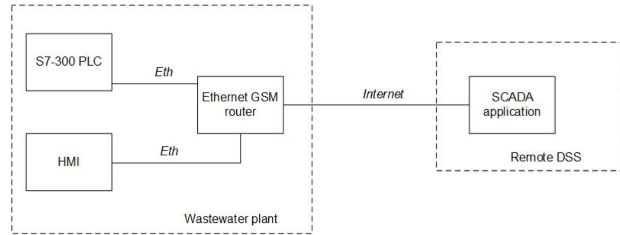

Fig. 1. Data transmission between site components

IV. REMOTE COMMUNICATION SETUP

We identified two possible solutions for the remote connection: using an OpenVPN configuration, or through an OPC tunnel integrated in a cloud application.

A. Communication using OpenVPN

We evaluated the integration of the local Siemens S7-300 PLC to the DSS through a secure VPN connection. The interconnection diagram is illustrated in Fig. 2.

To set up the VPN connection we installed a Spectre v3 router from B+B SmartWorks and configured it as a VPN client. A VPN server was installed on SIS's remote site using OpenVPN. By installing specific certificates generated for this application, we can connect many VPN clients to the server using a standard internet connection, and not necessary a fixed external IP. This increases the flexibility and minimizes the installation requirements for a possible beneficiary.

OpenVPN allows to create a secure connection over the Internet using client-server model of communication. OpenVPN tunnel configuration was created between the following equipment:

- ASUS RT-AC56U router – the server. WAN connection is residential type subscription (public and dynamic IP – a DDNS free service provided by ASUS is used to return the IP address to client at any given time).
- B+B SmartWorx powered by Advantech Spectre V3 LTE router – the client. WAN connection is postpaid mobile type subscription (IP address is not public).

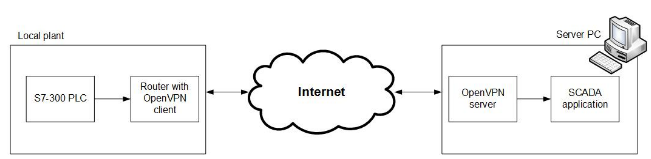

Fig. 2. Remote data acquisition and control using OpenVPN

The connection of a new plant to the DSS system implies only the reconfiguration of the devices IP, the configuration of the router to be a new VPN client, and the configuration of the mobile network according to existing operators in the plant area. Each PLC, HMI and router for all interconnected plants will be accessible as network resources of the VPN server from any of the supervisory stations in the DSS.

B. OPC Tunneling

The remote data acquisition can also be accomplished using specialized software tools from Skkynet and Cogent. These tools allow the data acquisition form the plant under strict security regulations and don't require any changes in the local network of the plant. Another benefit of this approach is that the network traffic is limited only to process data, increasing data collection efficiency at the DSS level and reducing communication costs for the beneficiary.

For the remote data acquisition using this configuration, the following are needed:

- Data is sent from the PLC using TCP or Modbus TCP protocol (PLC acts as Modbus slave);
- Data is received by an ETK-enabled router. We configured a Spectre router with the ETK driver;
- Data is sent through Skkyhub to a Cogent DataHub application that acts as a Modbus TCP master;
- Cogent Data Hub makes the data available through OPC to be included in the remote SCADA application.

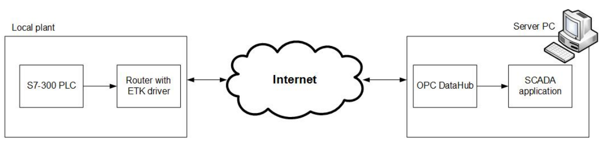

Fig. 3. Remote data acquisition and control using OPC tunneling

The solution identified for the data acquisition can be easily applied to our control system, as it does not require any installation of software products on a PC, but some minor additional configuration will be needed in the control strategy to make the data available through Modbus TCP.

C. Implementation

Testing of the VPN option was done using an ASUS router. The router was configured as a VPN server and the connection certificates were generated. This router's information was then entered in the plant router configuration (Fig. 4).

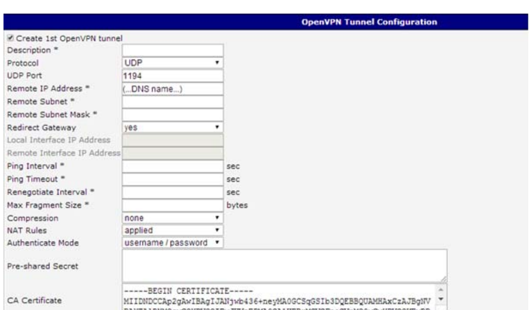

Fig. 4. VPN client router configuration example

For the implementation of the OPC tunnel we used Cogent DataHub [8]. It can connect to another Datahub, installed in another network, by using his domain name or his IP address and port. The connection information was configured in the client application (Fig. 5).

The server part of the tunnel must have the correct port available for listening and opened for connections. The Datahub is using OPC DA for data transmission between ends of the tunnel. The results for an initial set of data acquisition in an OPC client application is illustrated in Fig. 6.

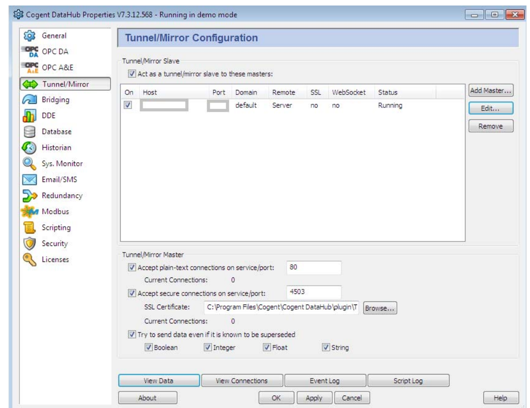

Fig. 5. OPC tunnel configuration example

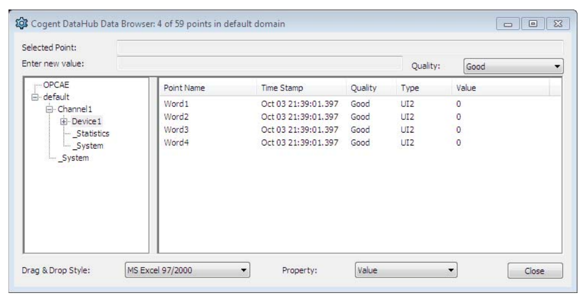

Fig. 6. Data aquisition

V. CONCLUSIONS

Remote plant monitoring and control becomes more accessible with the latest technologies that provide reduced latency even for mobile communications. To benefit most from these advances, reduced cost and secure solutions can be implemented without the acquisition of a public IP from the services providers. This paper presented and tested two such configurations for a typical PLC to a remote decision support system connection. Results showed that such architectures enable greater accessibility and improved plant operations.

Future work will include performance evaluation between these two options and the implementation of algorithms for wastewater plant operation optimization.

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