

DOE/FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

For June 16, 2008 to August 22, 2008

Waste Treatment Plant (WTP) – Pre-Engineering Platform (PEP) Automated Operation Control via Programmable Logic Controllers (PLC)

Principal Investigators:

Serkan Akar (DOE Fellow Student)
Florida International University

Joseph (Jake) Tucker, Sr. Engineer, Mentor
Pacific Northwest National Laboratory

Acknowledgements:

Gary Josephson Manager
David Clark, Programming Engineer

Florida International University Collaborator:

Leonel E. Lagos, Ph.D., PMP®

Prepared for:

U.S. Department of Energy
Office of Environmental Management
Under Grant No. DE-FG01-05EW07033

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, nor any of its contractors, subcontractors, nor their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe upon privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any other agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

ABSTRACT

A programmable logic controller (PLC) is a digitalized computer system used primarily for the automation of industrial processes. There are various types of PLC models commercially available and the main purpose of the PLCs are to allow operation from a computer screen or to automatically control the operations. PLCs are designed for multiple inputs and outputs, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact.

PLCs are utilized in the pre-treatment engineering platform (PEP), which is a scaled mock-up model of a waste treatment plant (WTP). PEP was developed to enhance the treatment system by controlling operations through a computer. All of the machinery in the PEP are controlled via PLCs. The control system consists of multiple PLCs (typically one per skid) networked to a common control station in a central control room (CCR).

TABLE OF CONTENTS

Abstract	ii
Table of Contents	iii
List of Figures	iv
1. Introduction	1
2. Executive Summary	2
3. Task Description	3
4. Results	11
5. References	12
6. Appendix A	13

1. INTRODUCTION

The Department of Energy (DOE) has developed a waste treatment plant (WTP) program to improve the safe storage of high level waste (HLW). One storage site for HLW is Hanford, WA. However, due to the limited storage space available and issues with the existing storage tanks, improvements in the management and storage of HLW are needed. Dedicated scientists and engineers at Hanford have developed a new method for treating and storing the waste. This new technique is used within the WTP to treat and vitrify radioactive waste stored in the underground tanks at the Hanford site. The treatment plant is designed to separate the HLW from the low activity waste (LAW), which is done via ultra filtration. The remaining concentrated HLW then undergoes a caustic and oxidative leaching process. This process helps to dissolve and eliminate any material that might limit the HLW loading into the stationary waste glass (e.g., aluminum, chromium, phosphates, and sulfates). All of these processes are repeated until the pre-treatment obtains a highly concentrated HLW.

Since this new method is theoretical, it needs to be thoroughly tested. Therefore, a pretreatment engineering platform (PEP), a mock-up scaled platform, was established to perform demonstrations and tests before a full-size treatment system is built on the site. The PEP's operations are controlled with programmable logic controllers (PLCs). The mock-up scale-model is constructed on seven skids (divisions) with each skid being responsible for a certain task within the PEP project. The skids are named P1 through P7, U1 and U2. For each skid, there is a corresponding PLC central processing unit (CPU) to ensure that the programmed operation is being performed. The PLCs are integrated with a Human Machine Interface (HMI) to allow users to perform operations, to do necessary programming-based troubleshooting from a computer, and to monitor all the functions being executed.

In addition to the PLCs that were already installed at the Process Development Laboratory (PDL), a test bed consisting of PLC CPUs was set up in the Mechanical CAD Laboratory where software updates are programmed and new engineers are trained.

2. EXECUTIVE SUMMARY

This summer internship research work has been supported by the DOE/FIU Science & Technology Workforce Initiative, an innovative program developed by the U.S. Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2008, an FIU-ARC student spent 10 weeks interning at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington, under the supervision and guidance of Dr. Gary Josephson and Senior Engineer Joseph (Jake) Tucker.

PLC systems that control all of the functions of the mock-up scale WTP project were studied in the Mechanical CAD Laboratory. A test bed that contains a set of PLCs, an exact imitation of what is installed at the PDL-West building, was established at the laboratory. PLCs ensure the automation of the programmed functions, such as motor operation, temperature, pressure, flow sensing, etc. In addition, a PLC is capable of comparing the values from the system and the written program, taking the necessary corrective action without human interference.

3. TASK DESCRIPTION

PLCs are the brain of the PEP. PLCs ensure the automation of the mock-up scaled WTP project by taking measurements and processing the received data. The control system consists of multiple PLC units (typically one unit per skid) networked to a common control station in a central control room (CCR). One complete unit is shown in Figure 1.

A PLC is made of the following 2 main parts and subparts:

1. Hardware

- CPU and Input Output Modules (e.g., AC 500 model shown in Figure 1)
- Computer



Figure 1. AC 500 Model PLC Unit with CPU and Input Output Modules.

2. Software

- HMI (Human Machine Interface) shown in Figure 2
- CoDeSys programming software shown in Figure 3
- Iconix software that establishes a communication between HMI and CoDeSys

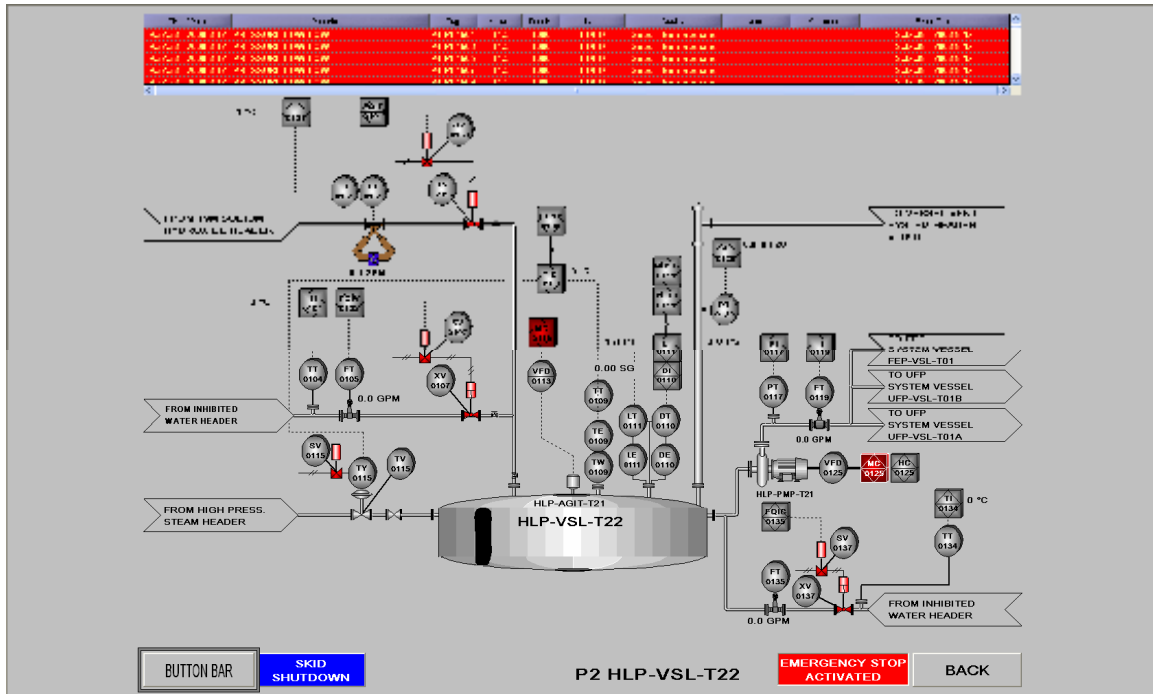


Figure 2. Human Machine Interface.

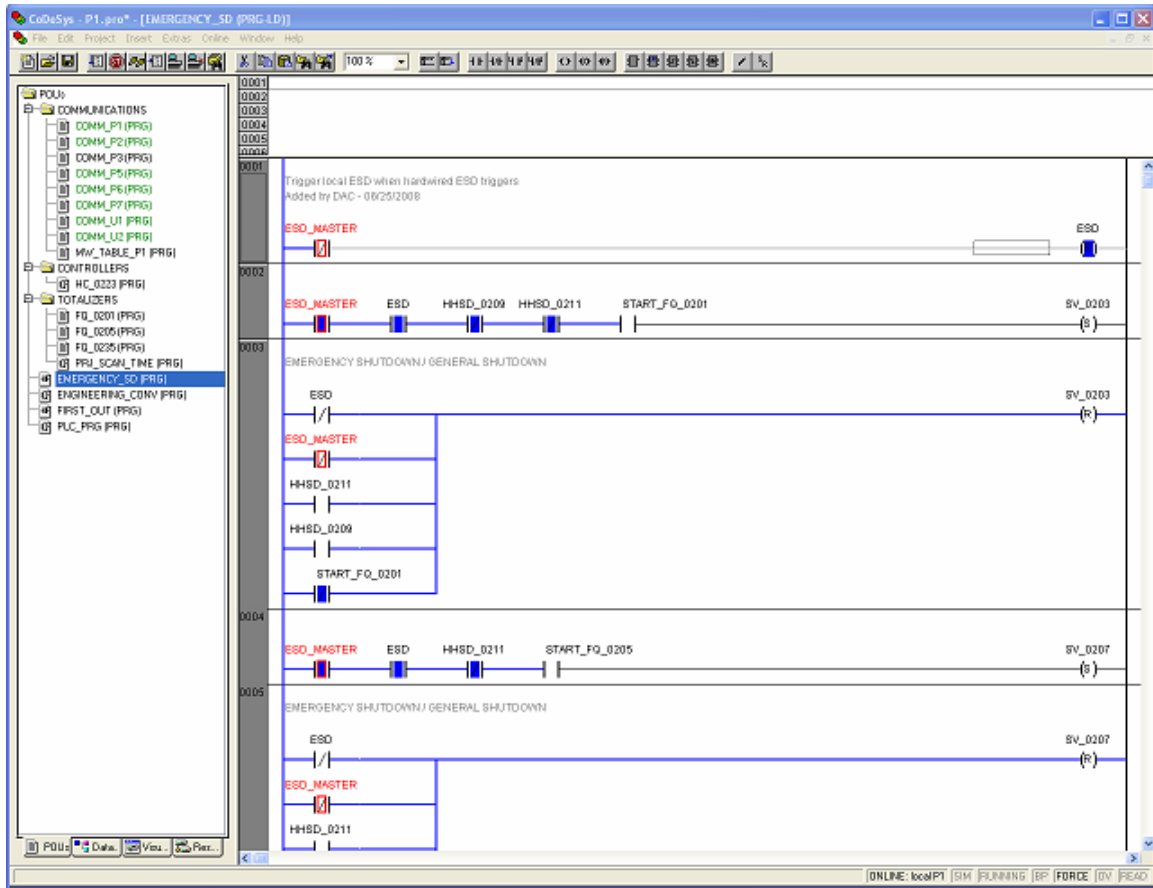


Figure 3. CoDeSys Programming Software.

The PLC hardware, along with its modules, are installed on the PEP and the sensor gages, motors and flow meters are wired to the input and output modules. The computer is where all the software is installed and operations are monitored. The HMI gives a visual image of all the equipment that is connected to the PLC's central processing unit (CPU) and the operations being executed. The HMI is connected to the programming software CoDeSys via Iconix software. CoDeSys is where the PLC codes are generated and compiled. CoDeSys software communicates with the CPU via the HMI; the Iconix software establishes a connection between the two. The connection scheme is shown in Figure 4. Once the program is generated, it can be stored in the CPU and ran without further interaction unless an update or correction needs to be made. One other advantage of using a PLC is to gain remote access via a modem connection. A user can log into system from anywhere and monitor all the operation once the modem connection is established. This feature is further explained in Appendix A.

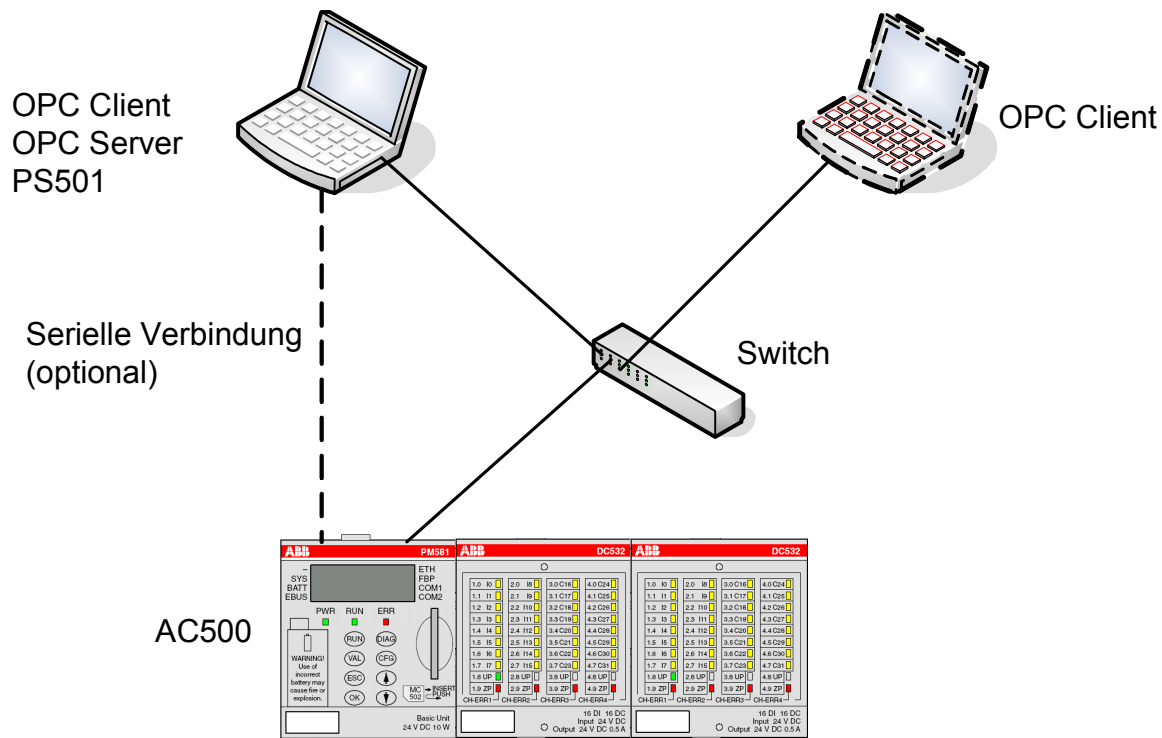


Figure 4. Connection scheme.

In order to minimize conflicts between points of operation, the following operational philosophy is applied:

- All PLCs (HMI) can view all systems.
- Each local skid PLC can only control equipment associated with that skid (e.g., the start vessel agitator).
- The common control station in the CCR can control all operations (e.g., inter-skid transfers).

The PEP has 2 types of operations that are controlled by the PLC and many sub-operations within the main ones, as follows:

a. Primary Operations

1. Simulant Feed Receipt
2. Caustic Leaching
3. Solids Concentration
4. Caustic Leaching
5. Re-concentration
6. First Solids Washing
7. Oxidative Leaching
8. Final Solids Washing
9. Solids Transfer
10. Filter Washing
11. Filter Cleaning

b. Support Operations:

1. Receipt/Stage
2. Sampling
3. Dilution
4. Mixing (Pump Recirculation, Pulse Jet Mixers (PJMs), Spargers)
5. Mixing (in-line)
6. Heating
7. Cooling
8. Reagent Addition
9. Transfer
10. Line Flushing
11. Filter Back-pulsing
12. Control
 - Pressure
 - Flow (Instantaneous and Totalized)
 - Temperature
 - Level
 - Density

In Figure 5, a simplified flow diagram of the progress is shown.

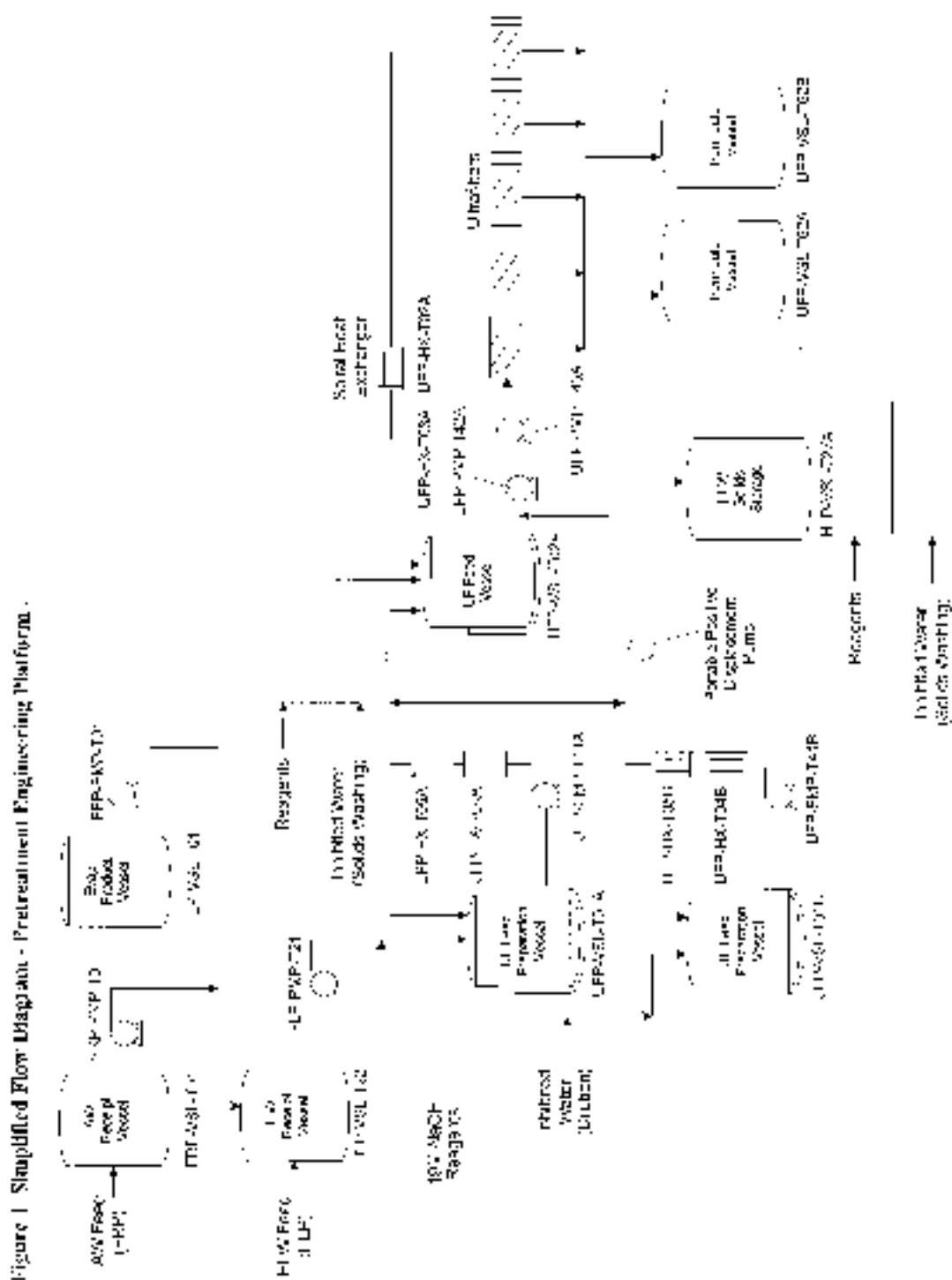


Figure 5. Simplified flow diagram for the pretreatment engineering platform.

When the PLC is activated (online mode), the format it follows is shown in Figure 6.

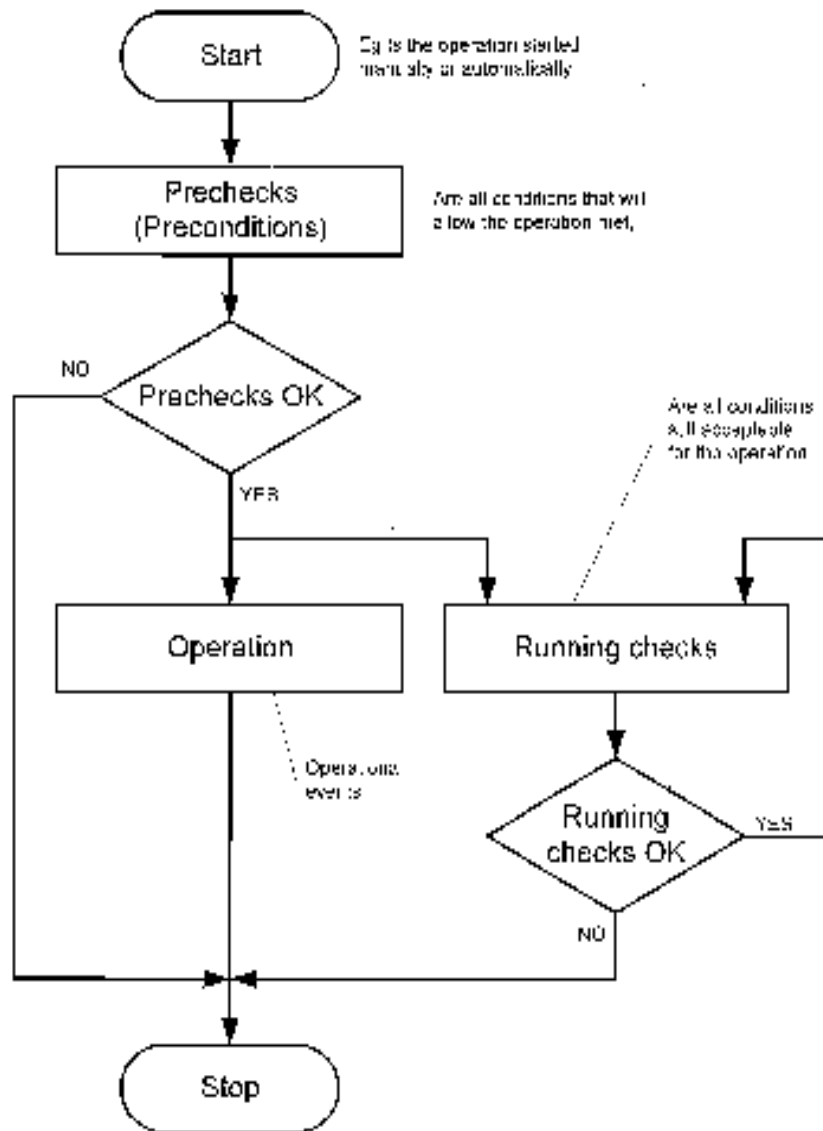


Figure 6. Operation format.

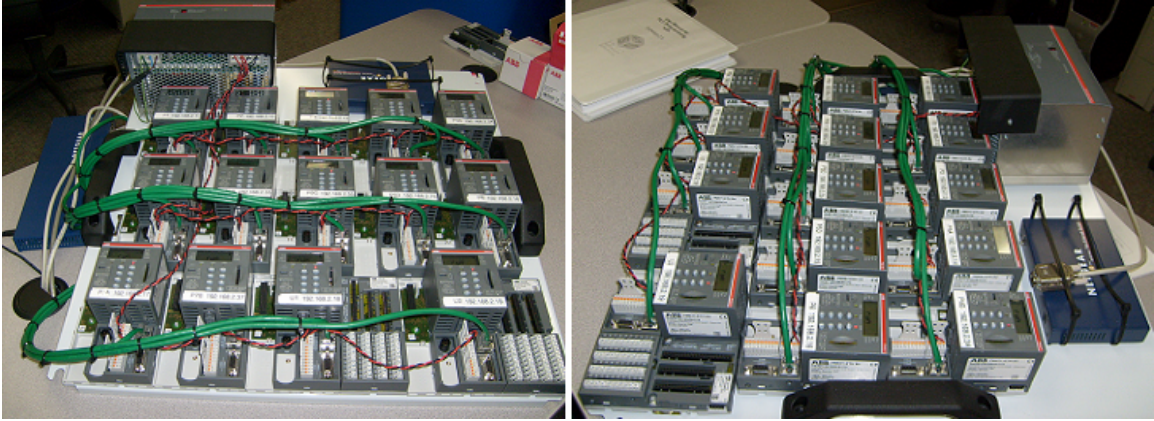
The functions mentioned above take place during the PEP operation in the order of the list provided and the format shown in Figure 6. The PLC ensures that the execution of these operations and computations are performed as directed by the written program. The program is executed in the format given in Figure 6. In any skid or at any given time, if an event is started in the PEP either manually or automatically, the PLC first checks the pre-conditions. After confirming the required criteria are met, the operation begins. In addition, the PLC always checks the running conditions to make sure the data are in the range of desired values. Then, running continues as it programmed. However, there are some circumstances in which operations are stopped, such as when a pre-condition check

fails or when the running check value goes out of range. This is a crucial format that PLC has to follow to guarantee desired operation performance.

The PEP must perform a demonstration on an engineering scale to validate the pretreatment facility (PTF) leaching and ultra-filtration processes (UFP) equipment design and sludge treatment process flow-sheet. The system has been designed using scaled prototypic equipment to demonstrate filtration rate, sludge water wash, caustic leaching (1nIJFP-VSL-T01AIB and UFP-VSL-T02A), and oxidative leaching. The unit operations to be tested include pumping, solids washing, chemical reagent addition and blending, heating, cooling, leaching, filtration, and filter cleaning. Therefore, updates, upgrades and corrections are to be made throughout the demonstrations to ensure the desired operation. Since the system is subject to changes, the engineers decided to develop a PLC experimental laboratory setup at the Mechanical Cad laboratory located at 2400 Stevens Building. The intern's assigned task was primarily to learn the PLC system and then help with the experimental laboratory setup development shown in Figures 7, 8 and 9.



Figure 7. PEP experimental lab setup.



Figures 8 and 9. PLC CPUs in a network connection.

4. RESULTS

As the intern had no experience with PLCs, his primary objective was to gain familiarity with the system. This process began with reading manuals and performing basic research on PLCs. The main questions that had to be answered before beginning work with the PLCs included the following: What is a PLC? How does it work? What project is it being used for? What does it control? The intern successfully accomplished this basic research and gained an essential understanding of the PLC technology.

The system used on the PEP project is an ABB brand AC 500 model and uses programming with PLC software CoDeSys. Engineers at the PEP struggled with the communication between the computer and the PLC. Due to the lack of customer assistance or technical support from the ABB company, someone had to dedicate sufficient time to read all of the technology documentation, perform research into how PEP works and define the requirements. Since the project was running behind, the scientists and engineers could dedicate very little time specifically to the PLC. Thus, the intern dedicated all of his internship hours specifically to the PLC. The intern successfully established a connection and set up the experimental PLC platform at the laboratory where programming engineers and operation engineers could use the system, correct mistakes, or diagnose the cause of a failed operation. Figure 7 shows a view of the system after the intern successfully completed his task.

5. REFERENCES

1. <http://www.hightech.com.au/PLC.htm>)
2. Evan Dresel, 2008, *Site Integration Testing Plan for the Pretreatment Engineering Platform Water Testing*, Pacific Northwest National Laboratory (PNNL), Richland, WA 99352.
3. Scott Lehrman, 2008, *Platform PEP Phase 1 Testing Process Description*, PNNL, WA.

APPENDIX A

REMOTE PROGRAMMING OF KT95...98 AND AC500

1. KT95...98 using AC1131	14
1.1 Modem	14
1.2 Cable PC \leftrightarrow modem1	14
1.3 Cable modem 2 \leftrightarrow PLC	14
1.4 Parameter settings modem 1 (PC side)	15
1.5 Parameter settings modem 2 (PLC side)	15
1.6 Use of Microsoft tool „Hyperterminal“	16
2. AC500 using PS501 (CodeSys)	16
2.1 Modem	17
2.2 Cable PC \leftrightarrow modem 1	17
2.3 Cable modem2 \leftrightarrow PLC	17
2.4 Parameter settings modem 1 (PC side)	17
2.5 Parameter settings modem 2 (PLC side)	18
2.6 Use of Microsoft tool „Hyperterminal“	19

1. KT95...98 using AC1131

PC with installed AC1131 ↔ modem1 ← telephone line→ modem 2 ↔ PLC

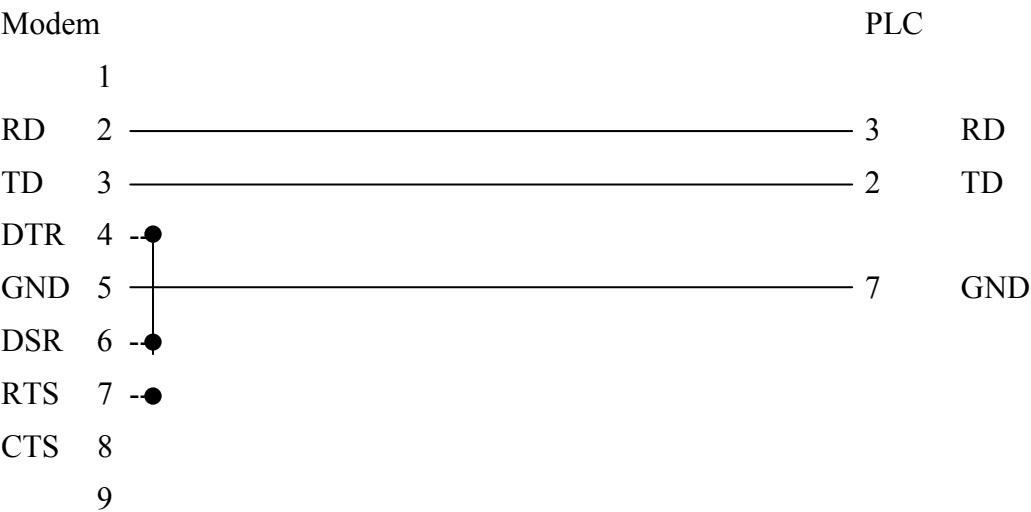
1.1 Modem

Test was run using HSM ECO V92 from supplier Comtime.
The AT command settings in this Appendix refer to this modem.

1.2 Cable PC ↔ modem1

Standard modem cable (with wiring) 1 : 1

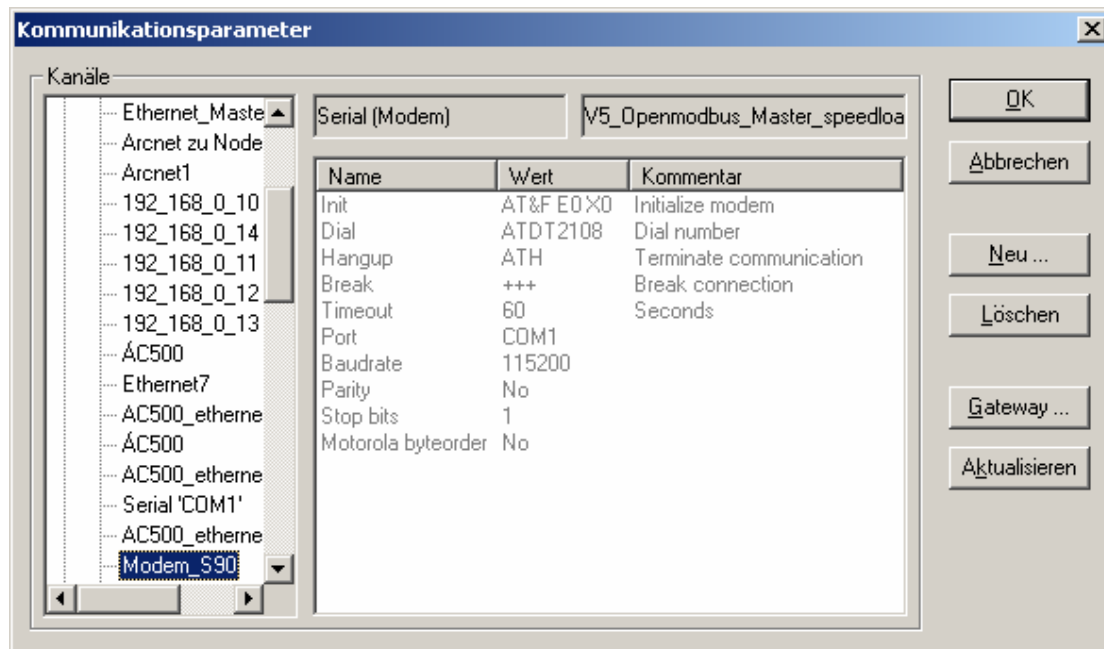
1.3 Cable modem 2 ↔ PLC



1.4 Parameter settings modem 1 (PC side)

Modem 1 PC side: No special settings at the modem are necessary.

Setting for the related modem driver in 907AC1131 are as shown below:



The settings shown above are for an internal telephone connection. For an external telephone connection, both “access digit” and “waiting period” have to be included in the dial-up string as follows:

ATDT0W91772108

| | _____ Waiting period
| _____ Access digit

1.5 Parameter settings modem 2 (PLC side)

Modem 2 PLC side: It's mandatory to set the parameters as follows:
19200bd / 8data bit / 1stop bit / No parity bit / no RTS/CTS

(Use Microsoft tool “Hyperterminal” or other)

Set: AT&F S0=1 E0 X0 &W

AT &F → Modem reset (load factory settings)

AT S0=1 → Pick up after 1.ringing tone

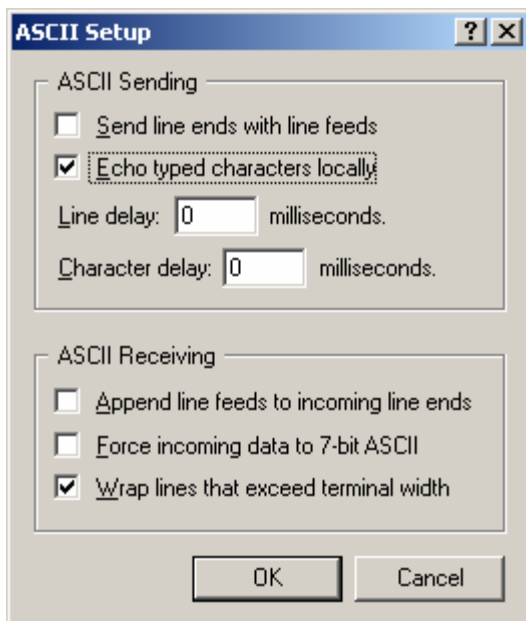
AT E0	→ Echo off in command mode
AT X0	→ Modem to respond with CONNECT
AT &W	→ Saving of active profile

1.6 Use of Microsoft tool „Hyperterminal“

→ Setting of „local echo“

File → properties → settings → ASCII setup

Check mark “Echo typed characters locally” → <ok> → <ok>



Test of connection to modem via “Hyperterminal”:

AT <enter>

OK → Response from modem

2. AC500 using CodeSys

PC with installed PS501 (CoDeSys) ↔ modem1 ↔ modem 2 ↔ PLC

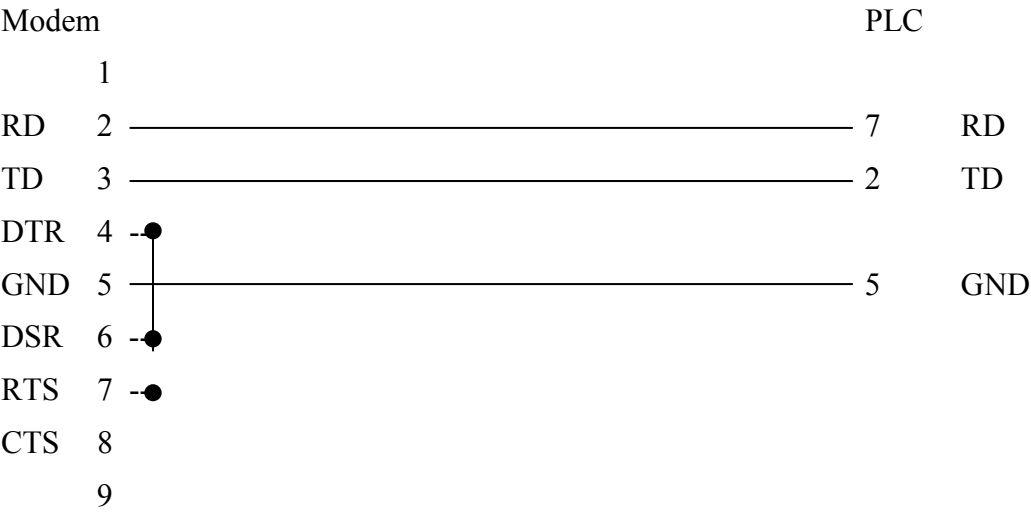
2.1 Modem

The test was run using HSM ECO V92 from supplier Comtime.
The AT command settings in this appendix refer to this modem).

2.2 Cable PC ↔ modem 1

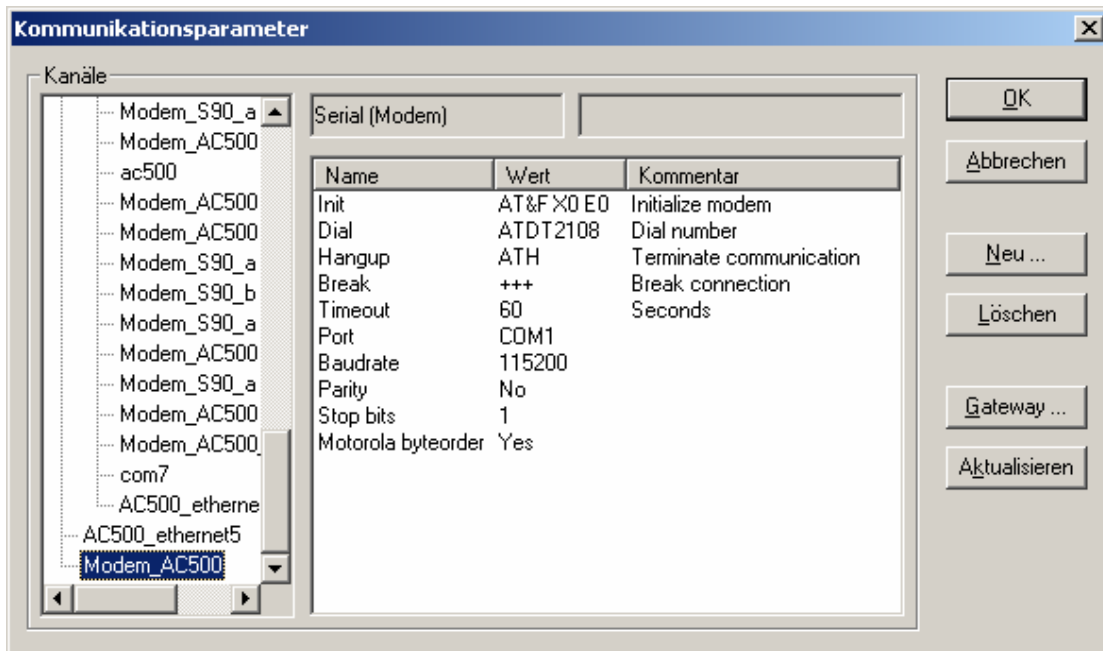
Standard modem cable (with wiring) 1 : 1

2.3 Cable modem 2 ↔ PLC



2.4 Parameter settings modem 1 (PC side)

Modem 1 PC side: No special settings at the modem are necessary.
 Settings have to be done for the related modem driver in
 907AC1131 as shown below:



The settings shown above are for an internal telephone connection. For an external telephone connection, both “access digit” and “waiting period” have to be included in the dial-up string as follows:

ATDT0W91772108

| | _____ Waiting period
 | _____ Access digit

2.5 Parameter settings modem 2 (PLC side)

Modem 2 PLC side: It's mandatory to set the parameters as follows:
 19200bd / 8data bit / 1stop bit / No parity bit / no RTS/CTS

(Use Microsoft tool “Hyperterminal” or other)

Set: AT&F S0=1 E0 X0 &W

AT &F → Modem reset (load factory settings)

AT S0=1 → Pick up after 1. ringing tone

AT E0 → Echo off in command mode

AT X0 → Modem to respond with CONNECT

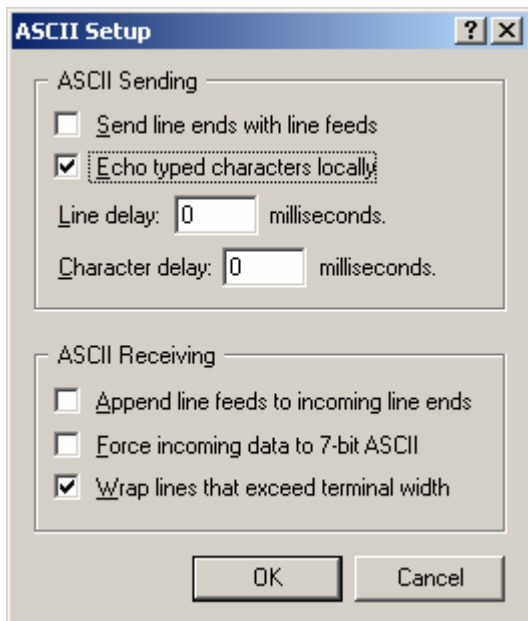
AT &W → Saving of active profile

2.6 Use of Microsoft tool “Hyperterminal”

→ Setting of „local echo“

File → properties → settings → ASCII setup

Check mark “Echo typed characters locally” → <ok> → <ok>



Test of connection to modem via “Hyperterminal”:

AT <enter>

OK → Response from modem