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Industrial Lab-Bench Liquid Level Process Control System Paper – Phase I

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***Abstract*—In this paper, a lab-bench of a water level control system is fabricated. The fabricated water level system consists of two water tanks and one supply tank with similar dimensions. In the lab-bench, one variable speed drive (VSD), one 3-phase 0.75kW motor, two linear variable displacement transducer (LVDT), one paddle wheel i.e. a water flow sensor as well as CX-Programmer and CX-Designer are incorporated into the design. The first phase of the project is to monitor and manually control the work bench utilizing CX-Programmer (PLC) and VSD. PLC Omron is used to control the system, meanwhile CX-Designer is used to provide a human machine interface (HMI) for the lab-bench. The first phase of the water level system is completed successfully with the proposed workbench successfully monitored and the motor speed is varied manually via VSD. Initial analysis of the sensors utilized are presented for future references for the next phase of the project. The fabricated system is capable to operate manually and automatically through a monitoring system utilizing CX-Programmer.**

Keywords— Water level system, Variable speed drives, Flowrate, Level transducer, SCADA, CX-Programmer, CX-Designer, Human Machine Interface

I. INTRODUCTION

For the purpose of industrial automation control process, a liquid level control system project is conducted. Ideally, this project is directly related to the fundamental of process control in which the main objective is to identify the relationship between the motor speed, water flow rate and water level.

A process generally act as an operation that utilizes resources from inputs to outputs. In the industrial applications, control of process variables is one of the important elements need to be considered to provide a safe and efficient operation of the process involved. The most common control variables are utilized in this project, which are water flow rate and the water level of the tanks. Accurate measurement of these variables is essential in the scope of water treatment and supply plants in order to provide effective operation. The level and flow measurements are obtained to estimate the amount of output produced for a specific production target which are widely used in the industrial process. In this project, typical components for level control systems which include pumps, motors, and valves are utilized.

The concept implemented in this project incorporates a three-phase motor pump, linear variable displacement transducer (LVDT) (level transducers sensor), a paddle wheel (flowrate sensor) and a variable speed drive (VSD). The function of the motor pump is for water transference from the input tank to the system tanks, the LVDT is used to measure the level of the tanks using pressure difference, meanwhile paddle wheel is used to monitor the speed of the water flow, into and out of the system tanks.

In this project, the water from the supply tank (input) is pumped by the three-phase motor pump which will pass through the first paddle wheel, i.e. the input water flow rate. Then, the water will enter either one of the two tanks of the system, determined easily by manually turning the valve ON and OFF. To measure the level of the tanks, LVDT is installed on each tank. Finally, the water will pass through the second paddle wheel, to monitor the output water flow rate. The frequency of the motor can be varied manually by adjusting the variable speed drives (VSD) through a human machine interface (HMI) of a CX-programmer, based on the tanks' levels.

II. LEVEL PROCESS CONTROL SYSTEM

Level process control system provides an experimental introduction to the fundamentals of flow and level control. In a typical level process system, the level and water flow rate can be controlled using a simple feedback control, or if a tighter control is required, cascade control can be applied. In a simple feedback control, the two variables can be controlled separately. Meanwhile, in a cascade control mode, by taking the water level as the primary controlled variable, water flow control can provide tighter adjustment as the secondary control variable.

Level determination in a process control works similarly as other process applications which requires measurement before any control function can be implemented. In this context, level process is implemented on water level or water level of tanks. However, since the control function is universal, it can also be used to control level of other substances such as solids or even mixture of substances in a particular tank. The control function of level process involved in turning a pump ON or OFF depending on the requirements or necessity of the system level. Control could be quite perplexing when continuous level monitoring is required for the system. Level determination of a process control is often considered to be a control function that could apply or integrate with several different processes that exists in a system.

The main focus of this project is to monitor the overall system and control the water flow from the reservoir i.e. the input tank to either tank A (lower tank) or/and B (upper tank) as well as controlling the water level for both tanks. The proposed workbench is depicted as a technical drawing in Fig. 1 below.

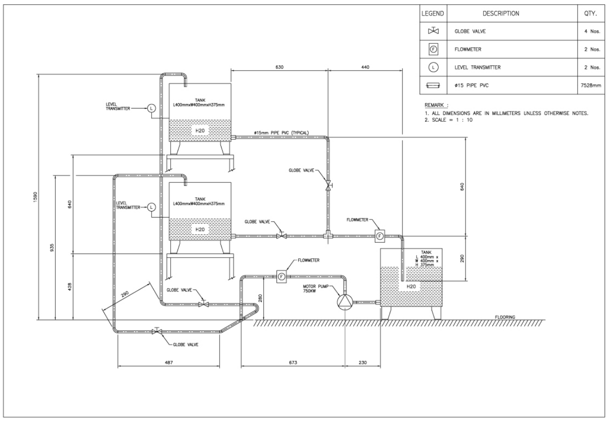

Fig. 1. Technical Drawing for the Water Level System

From Fig. 1, prior to turning the water pump motor ON, the operating mode must be selected from the HMI, which is automatic or manual. Once the start button is selected, the motor will start at a pre-defined frequency of 25 Hz, displayed on the VSD. The frequency of the motor can be adjusted based on the set point values of the water flow rate and water level of the tanks. Initially, the water will start to flow from the input tank into tank A. LVDT A will send signals to the PLC on the height of water in the tank. The water will fill up tank A until the maximum level is reached. Then, valve B will be opened to let the water flows into tank B until the maximum height is reached. LVDT B will update the water level to the PLC. The level of the water in both tanks will be displayed on the HMI screen. Meanwhile, the water flow rate of both tank A and B will be displayed on the HMI screen. All the data will be extracted and transferred to the CX-Supervisor for further improvement of project in terms of real-time monitoring. As an extra precaution, safety warning light will be triggered when there are faulty in either the water pump motor or the utilized sensors.

For the software development of the project, to write the control program of the system, CX-Programmer version 9.5 is used. In this project, PLC ladder diagram, with the help of VSD, is used to monitor and control the water level and water flow from the flow meter to the corresponding voltage value between 0V to 10V. Then, ladder diagram instruction is used to program and run the PLC either manually or automatically to control the water pump motor which is based on the input status given by the operator through the HMI. Through the operator HMI screen, the SCADA system is able to monitor and control the real time operation system. This will ease the system operation through virtual real-time monitoring. Finally a complete SCADA is created by interfacing the ladder diagram for the whole system via CX-Programmer and the Graphical User Interface via CX-Supervisor.

III. SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM

Supervisory Control and Data Acquisition (SCADA) system provides remote monitoring and control system and currently has becoming a backbone of many process industries. The implementation of SCADA in WTP and Wastewater Treatment Plant (WWTP) can be seen in [2,3]. In these plants, SCADA is used to provide real-time application management environment by providing tools for implementation and testing of sophisticated control system and data quality analysis. Guides on implementing SCADA properly can be found in [4], whereby the case study of a WWTP is used.

Some important features of the supervisory control and data acquisition (SCADA) system in waste or wastewater treatment plant are Control, Monitoring, Alarming, Data logging and Diagnostic [10]. In control features, maintaining specific levels in tanks and retaining prescribed flow rates, can be easily achieved in SCADA system by consecutive standard control algorithm such as P, PI, and PID. By implementing Boolean Logic, controlling the application scheduling such as automating starting and stopping pumps, opening and closing valves and others can also be done in SCADA system.

Another coveted feature of SCADA system is data logging. When data are conveyed into a system, the SCADA will document selected data into electronic records that may be recollected and reviewed at a later time. By utilizing the historical data, further analysis or reports can be prepared. Through historian function, such as record on the track energy charges and consumption, bill validation and report on cost avoidance can be trailed. In addition to that, data logged from SCADA can be conveniently used for analysis to further improve the plant operation, as an aid for decisional support mechanism [7].

A. Programmable Logic Controller

Programmable Logic Circuit is the most important element in a SCADA system. PLC is a microprocessor-based control system created for automation processes in industrial environments [6]. The purpose of a PLC is to replace the electromechanical relays as logic elements, subbing instead a solid state digital computer with a stored program, able to emulate the interconnection of many relays to perform certain logical tasks. A PLC has many “input” terminal, through which it interprets “high” and “low” logical states from sensing element and switches. It also has many output terminals, through which it reads outputs “high” and “low” signals to power lights, solenoids, contactors, and other devices loaning themselves to ON or OFF control. In order to make PLCs easy to program, a programming language is designed to resemble ladder logic diagrams [5]. Thus, in this project, PLC ladder diagram will be fully utilized to perform the automatic control algorithm.

B. Human Machine Interface

Mischances in machines are regularly credited to human mistakes. Nonetheless, when these mishaps are scrutinized further, it is discovered that they are in certainty caused by poor ergonomic plan of the interface or by issues of association between the machine and the client instead of by careless or reckless utilization. As a result, Human Machine Interface is introduced to reduce human error and ease the system control [4].

HMI incorporates programming and equipment that enables human administrators to screen the condition of a procedure under control, adjust control settings to change the control objective, and physically nullify programmed control operations in case of a crisis. Likewise, HMI enables a client to arrange or control calculations and parameters in the system, easily [8]. HMI is capable to show data status, verifiable data, reports, and other data to administrators, executives, chiefs, business accomplices, and other approved clients [11]. For instance, a HMI could be a committed stage in the control focus, a tablet on a remote LAN, or a program on a system associated with the Internet. In this project, the HMI utilized to monitor the level and flow rate of the system, as well as controlling the frequency of the VSD.

C. Communication Network

Without an appropriately planned communication network system, a SCADA framework cease to exist. All supervisory control and information obtaining parts of the SCADA system depends completely on the correspondence framework to stream information between the supervisory controls, the information procurement units, and any controllers that might be connected to the system [12]. The communication network is essential for a SCADA system to associate the RTUs with the SCADA Master.

While many power, electric, and water organizations still utilize physical work to perform estimations and alterations, these assignments can be effectively robotized with SCADA system [1]. With utilization from automation in a system, work expenses can be cut and limit mishaps with estimations or alterations. It might appear that SCADA system is simply a process to store information in a circulated database, yet there is substantially more intricacy to the framework itself.

The framework gives various advantages over difficult work, for example, repetition modifications, stable reinforcements of time stamped information, and a protected caution framework. Rather than utilizing people to check for failures of the plant, matrix, or pipeline, SCADA utilizes scripts that detect problems in the system, and quickly adjusts the system from creating an uncontrollable outcome [4]. On the off chance that a failure were to occur, a SCADA framework's circulated database would help operators to recognize the area in question briefly. Additionally, the automation system fundamentally expands the time of energy restoration that comes with an outage; from the control room, at the press of a button, a worker can enable switches and help reroute power to unaffected sections.

IV. METHODOLOGY

In this project, to design the software programming, CX-Programmer is selected to write a program in the Programmable Logic Controller (PLC), which is represented as SCADA RTU. CX-Programmer is used to create ladder diagram to command the system based on feedback received, so that the system is able to respond properly in any conditions. In earlier progress, CX-Designer is used in developing SCADA Interface. However, it does not suitable for industrial use because it only provides simple applications for learning process of HMI. In contrast, CX-Supervisor boasts powerful functions for a wide range of PC based HMI requirements [10]. Then, CX-Supervisor is chosen to be developed as Human Machine Interface (HMI) of SCADA system. It is able to animate the system in real-time operation, and have the option to monitor and record the data received to Microsoft Excel. Therefore, it helps to save time for on-site monitoring and easier data documentation. Hence, there are a total of three softwares that will be used for SCADA system; CX-Supervisor, CX-Programmer and Microsoft Excel.

V. RESULTS

During the system integration of the system hardware and software, calibration of the sensors to the data obtained by PLC is crucial. The data collected will be used to build an appropriate program that is able to synchronize with the system properly. A ladder diagram in PLC can then be designed to produce output to the HMI.

A. Level Variable Displacement Transducer (LVDT)

The dimensions for Tank A and Tank B are the same. Calibration test confirmed that the LVDT is in good working order and a linear relationship is obtained between the potential difference of the level sensor and the tank level. The reading taken for an interval time of 15 seconds, with the motor frequency set at 25Hz is given in Fig. 2. From Fig. 2 below, it is apparent that a linear relationship exists between the level sensor and the actual tank level.

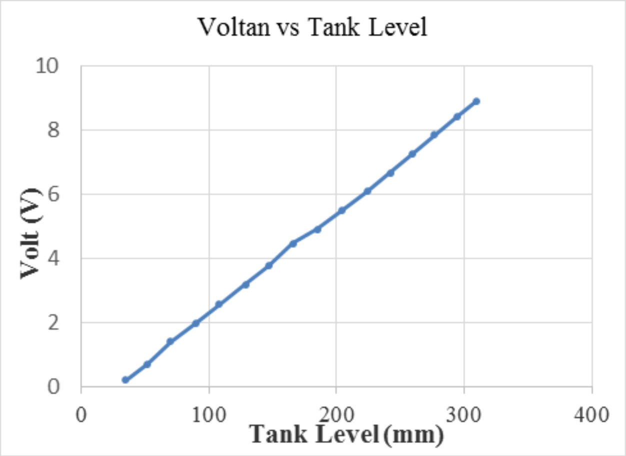

Fig. 2. Linear relationship between LVDT and tank level

With a simple scaling ladder diagram programming in PLC, the true value of the tank level can be displayed in the HMI.

B. Human Machine Interface

In the earlier progress development, CX-Designer is chosen to develop Human-Machine Interface (HMI) for the system. It is found to be more preferable among engineering students for its simplicity and easy to understand technique. A simulation performed in CX-Designer during learning process for SCADA system. Then, CX-Supervisor is selected as SCADA system interface for its powerful capabilities and suitability to be used for complex process. The human machine interface is designed as shown in Fig. 3.

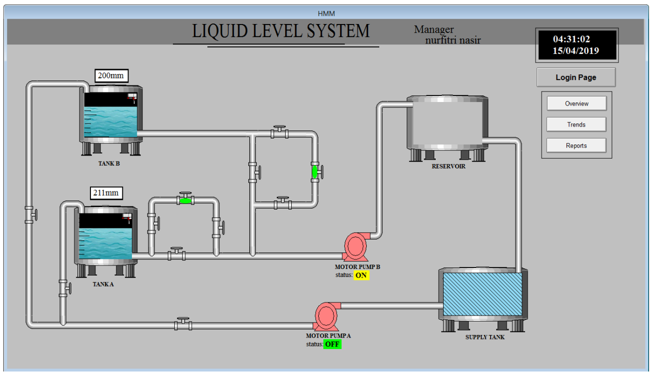

Fig. 3. HMI for the lab-bench

C. PLC Ladder Diagram

The calculation of inlet water flow rate into the system can be calculated by PLC. A ladder diagram for the scaling system is given in Fig 4.

Fig. 4. Ladder diagram for flow rate calculation in manual mode

From Fig. 3, once the manual start button for flow rate calculation is selected on the HMI, the program will start. As an example, of the water level reading, once the program starts, the reading of the water level in the tank will be moved from one data memory, say D18 to another data memory, say D100. After 5 seconds, the water level reading will be moved again from D18 to a new data memory of D101. Then, the value in D100 will be subtracted from the value in D101 and will kept in D102 and D103. The value in D102 and 103 will be multiplied by a variable, which is the surface area of the tank and divided by 5 seconds. Hence, flow rate will be produced and will kept in D104. Finally, the value will be displayed on HMI for the operator to view.

VI. CONCLUSION

In this project, a water level process system is fabricated which mimics a real water treatment plant, with successful system integration to a HMI developed by CX-Designer. In this first phase of the project, the level of the two tanks are successfully scaled and monitored from the HMI. Meanwhile, the speed of the water pump is successfully controlled by the variable speed drives. The next phase for the level process system is to install a second water pump for the water outlet as well as to monitor the power usage of the system.

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REFERENCES

[1] V. Rajeswari, L. Padma Suresh & Y. Rajeshwari, "Water storage and distribution system for pharmaceuticals using PLC and SCADA", *Proceedings of IEEE International Conference on Circuit, Power and Computing Technologies, ICCPCT 2013*, 2013, 79–86. http://doi.org/10.1109/ICCPCT.2013.6528951

[2] Archana, B. Yadav, PLC & SCADA based automation of filter house, a section of Water Treatment Plant, 1st International Conference on Emerging Technology Trends in Electronics, Communication and Networking,1-6, 2012. DOI 10.1109/ET2ECN.2012.6470057

[3] Humoreanu, I. Nascu, Wastewater Treatment plant SCADA Application, IEEE International Conference on Automation Quality and Testing Robotics, 575-580, 2012. DOI 10.1109/AQTR.2012.6237776

[4] Korodi, J. Silea, Specifying and Tendering of automation and SCADA system: Case study for waste water treatment plants, IEEE Conference on Control Application, 1503-1508, 2014. DOI 10.1109/CCA.2014.6981537

[5] A. Fazwan & A. Awalludin, "Monitoring and Controlling Double Carriage Elevator System Using CX-Designer and CX-Programmer", *2015 IEEE 6th Control and System Graduate Research Colloquium (ICSGRC)*, 2015, 151–157.

[6] A. Jafari & S.H. Patil, "Implementation of PLC remote monitoring and intelligent system of glazier machine", *Proceedings - UKSim-AMSS 7th European Modelling Symposium on Computer Modelling and Simulation, EMS 2013*, 2013, 349–352. http://doi.org/10.1109/EMS.2013.59

[7] B Stoian, D. Capatina, S. Ignat, O. Ghiran, SCADA and modeling in water management, International Conference on Automation, *Quality and Testing Robotics,* 1-6, 2014. DOI 10.1109/AQTR.2014.6857920.

[8] H.V.P. Singh & Q.H. Mahmoud "EYE-on-HMI: A Framework for monitoring human machine interfaces in control rooms:, *2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE)*,2017, 1–5. http://doi.org/10.1109/CCECE.2017.7946695

[9] U. Younas, S. Durrani & Y. Mehmood, "Designing Human Machine Interface for Vehicle's EFI Engine Using Siemen's PLC and SCADA System", *Proceedings - 2015 13th International Conference on Frontiers of Information Technology*, FIT 2015, 205–210. http://doi.org/10.1109/FIT.2015.44

[10] Humoreanu and I. Nascu, "Wastewater treatment plant SCADA Application," in *Automation Quality and Testing Robotics (AQTR), 2012 IEEE International Conference on*, pp. 575-580, 2012.

[11] J. Reeser, T. Jankowski, & G.M. Kemper, "Maintaining HMI and SCADA systems through computer virtualization", *IEEE Transactions on Industry Applications*, 2015, 2558–2564. http://doi.org/10.1109/TIA.2014.2384132

[12] F.Y. Zainal, & N.A. Rahim, "Implementation of IEC 60870-5-101 protocol on condition monitoring of water pump system", *3rd IET International Conference on Clean Energy and Technology (CEAT) 2014*, 2014, 1–5. http://doi.org/10.1049/cp.2014.1517