CENTRALIZED WATER DISTRIBUTION CONTROL AND MONITORING SYSTEM USING SCADA

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MAY 2012

"I hereby declare that I have read through this report entitle "Centralized Water Distribution Control And Monitoring System Using Scada" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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A report submitted in partial fulfilment of the requirements for the Degree of Bachelor of Industrial Power Engineering

Faculty of Electrical Engineering
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I declare that I have read through this report entitle "Centralized Water Distribution Control and Monitoring System Using SCADA" and found that it is the result of the student research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This project describe a monitoring and controlling system using Supervisory Control & Data Acquisition (SCADA) system which can be applied to go beyond the conventional water distribution system and solving problems faced by some of the water distribution system in rural areas. The main objective is to propose a method for rural area's water distribution system by providing effective controlling and monitoring system using Scada by implementing field data interfaces device with automatic control strategies based on water flow rate and pressure using PLC. The water distribution system prototype consists of water flow sensors, 2-way solenoid valves and pumps to control the flow of water under adequate pressure in the whole centralized system. The whole control process starts when the Programmable Logic Controller (PLC) collects input signal from the water flow sensors that indicates the level of the water in the tank. PLC will act accordingly to the input signal received and send it to the valves and pumps to proceed based on the tank level, such as turning the valves on or off automatically. Scada system will detect the events that occur in the whole system, carrying out necessary analysis, and displaying the information in a logical and organized way on the PC (SCADA) in the forms of tables, graph and reports. The concept of this project aims to increase the consistency of the water flow under constant pressure by controlling the operation of the valves and pumps using PLC based SCADA in a centralized water distribution system.

ABSTRAK

Projek ini menjelaskan tentang pemantauan dan pengawalan sistem pengagihan air dengan menggunakan sistem kaedah penyeliaan kawalan dan perolehan data (SCADA) yang boleh menjangkaui teknologi sistem pengagihan air yang bersifat konvensional. Selain itu, ia juga dapat menyelesaikan masalah yang dihadapi oleh sistem pengagihan air di kawasan pedalaman. Objektif utama projek ini adalah untuk mencadangkan satu kaedah untuk memperbaikikan sistem pengagihan air di kawasan pedalaman dengan menyediakan sistem penyeliaan dan pengawalan yang efektif dengan menggunakan Scada. Kaedah ini dapat dilaksanakan dengan mengimplikasikan peranti input dan output dengan kawalan automatik oleh PLC berdasarkan kadar aliran air dan tekanan air dalam sistem pengagihan air tersebut. Prototaip untuk sistem pengagihan air terdiri daripada sensor perbezaan tekanan sensor, 2/2 masukan injap solenoid dan pam lambung untuk mengawal kadar aliran air di dalam sistem pengagihan air berpusat tersebut. Proses pengagihan air bermula apabila PLC menerima dan mengumpul isyarat daripada perbezaan tekanan sensor. Setereusnya isyarat akan diproses berdasarkan tahap ketinggian air di dalam tangki dan seterusnya dihantar kepada injap dan pam untuk membuat tindakan yang seterusnya seperti memutarkan injap pada posisi "on" ataupun "off" secara automatic. Sistem kaedah penyeliaan dan perolehan data (SCADA) dapat mengesan kejadian yang berlaku di dalam keseluruhan sistem pengagihan air , menjalankan analisis yang diperlukan, dan memaparkan maklumat dengan cara yang logic dan teratur pada PC (Scada) dalam bentuk jadual, graf dan laporan. Konsep projek ini bertujuan untuk meningkatkan konsistensi kadar aliran air di bawah tekanan malar dengan mengawal operasi injap dan pam yang menggunakan SCADA berasaskan PLC dalam sistem pengagihan air yang berpusat

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CHAPTER 1

INTRODUCTION

This chapter describes the problem statement, project objectives, and scope of the project. Problem statement explains the issues/problems which initiates the purpose of this project. In project objectives, it states the goals that have to be accomplished in this project in concise terms, while project scope explains the limits and boundaries of this project.

1.1 Problem Statement

In rural areas, some water distribution systems are not well maintained, causing water leakage in the system. Water leakages are usually caused by leaking at piping system or loose valves at the water inlet and outlet. This will eventually reduce the consistency of water flow at the end of the water distribution system and also create unbalanced water pressure in the pipes of the distribution system. To maintain the whole control process of water distribution in the whole region is complicated as it does not only comprise of the main water distribution system but other pumping stations as well. A solution is possible, which is to create a centralized water distribution system which consists of a central unit and several pumping stations, controlled and monitored by SCADA system to help boost up the efficiency of the water distribution system. With SCADA, real-time monitoring and analysis is possible for a large water distribution system and also to detect the real-time data of the water flow in the system.

1.2 Project Objectives

The objective of this project is to develop a centralized water distribution system with effective controlling and monitoring system using SCADA. To achieve the goal, this project intends to meet several objectives as below:

a) To propose a method for rural area's water distribution system by providing an effective controlling and monitoring system using SCADA.
b) To design and create a centralized water distribution system prototype monitored and controlled by PLC based SCADA
c) To analyze the the effectiveness of PLC based SCADA system in water distribution system prototype.

1.3 Project Scope

This project focuses only on the water distribution system in rural area. Rural area in general are areas that are not urbanized, have low population density and mostly the land is devoted to agriculture. In Malaysia's Rural Master Plan, it is defined as "Area outside urban including settlements with population less than 10,000 people, agriculture area, and forest and water bodies".

The prototype consist of one main distribution system and two sub-station, and its operation of control and monitoring process will be centralized by using PLC based SCADA. SCADA is used to monitor the continuous flow and the pressure of water in the centralized water distribution system prototype.

Either Programmable Logic Controller (PLC) or Remote Terminal Unit (RTU) is used to control the valves and pumps in the centralized water distribution system prototype. Comparisons between PLC and RTU reveal mostly similarities in input/output hardware and also in programming languages.

Both are used for automation process such as control of machinery. They are designed for multiple inputs and outputs arrangement, extended temperature and resistance to vibration and impact. Advantages of using PLC and RTU is that there are both cost

effective for controlling complex system and high flexibility to control other systems quickly and easily.

Variables in this project are the water level and pressure of water in the tanks and pipes.

CHAPTER 2

LITERATURE REVIEW

Description of the literature is based on its content related to the Centralized Water Distribution Control and Monitoring System Using SCADA. In this chapter, the main source of this project discussed about the water distribution network system, types of controlling and monitoring using peripheral devices to human machine interface (HMI), and criteria needed to increase the efficiency of water distribution system.

2.1 Water Distribution Network

Populations in urban area are increasing as well as the demand of higher quality of water supply. Water supply system forms an important part of the urban infrastructure, therefore the continuity of the water distribution, monitoring and control of the process parameters, storage capacity of tanks and increasing diversity of water usage have to be assured [1]. According to [2], have shown that water distribution system was improved by using PLC/RTU based SCADA system via global online monitoring and water theft monitoring system by installing flow sensors at certain channels. Hence reducing operating cost and decrease of water losses can be achieved with implementation of an intelligent control system, with optimization of functional strategy and equipment. In other words, implementing automation system in to the water distribution network provides update to the water supply urban utilities. There is clearly a scope here for a great deal of research that is based on rural areas, which can be done by applying an intelligent automated control system to its water distribution system to increase its efficiency and continuity water supply system to upgrade the quality and comfort of living in rural areas.

According to [3], water distribution in urban area had greatly improved the overall economic development in that country, as well as the country's productivity. Development of water distribution system in rural areas can be considered as it may encourage rural resident from leaving the rural areas to urban areas when their living quality has been improved which can lessen the pressure on urban city [3]. It seems to be more difficult to plan the water system in rural areas than in urban area as the population at rural residential area are more scattered and widely distributed. Plus the urban areas have more expertise to control the water distribution system and to maintain the whole system, only a small group of technician is required to for the work. As for the rural area, to maintain a water distribution system, it needs to have a well trained technician to repair the system. But with the involvement of the villagers in the planning and construction of the water system network, the success of water development in rural areas can be achieved for long-term usage and maintenance.

2.1.1 Types of Water Network

A number of approaches for controlling and optimizing the monitoring system of water distribution network have existed since years ago to increase the efficiency and lower the operating cost in a water distribution network system. For instance, Qian Hua Xiao et al. [4] reported that conventional way using PID to control the liquid tank output level is hard and not efficient. Furthermore, the output flow of the liquid normally depends on the capacity of the water tank and its level of liquid in the tank. The new strategy is to control the liquid level in tank using fuzzy control method in MATLAB environment. Liquid level control system is an important system to detect the real-time data for the water flow, which can be applied at numerous fields.

Another approach is also presented by Florian Dotsch et al. [5] who's introduced the technique the so call self–organizing emergent system for real-time control of a water distribution network by decentralized the whole system. In this approach, it assumes that each pumps and tanks are equipped with an agent to communicate with each other to minimize energy cost and with higher flexibility when compare to human operator. It is based on a biologically-inspired technology, called "indirect defence" which operates based on chemical stimuli info chemicals via decentralized coordination mechanism.

The system proposed can be treated as an optimal solution and can be combined with the existing system in order to promote cost efficiency. This is the direction that can be considered in future, increasing the efficiency of the demand or an approach to deal with other conditions that revolve the distribution of water.

Centralized water distribution system is well approached by many other researchers as it provides permanent solution in order to develop a lower-cost water distribution system compared to other industrial solutions. For example, [6] presents an approach for optimizing and improving the efficiency of existing water distribution network by centralized monitoring. In some areas, improper water distribution network leads to wastage and inefficiencies in utilization of scarce resources of treated water especially in rural areas. In this case, it is to determine a way to improve efficiency in conventional network which requires central monitoring and controlling the functionality of the water distribution network by replacing PLC with operable three interchangeable modes, manual, auto and remote. This system has been tested under different operating condition and is aimed to optimize future water distribution in the country.

By using Matlab environment in fuzzy control method, controlling and monitoring the water tank level can be much easier, effective and achieve precise control over the output flow from the liquid tank. However, it is not easy to fully understand the Matlab software as it has many other function as well. As for the second approach, it proves that it is cost reductive yet efficient by implementing self-organizing multi-agent into each of its peripheral devices to communicate directly with each other without using expensive sensors. However, in this approach it uses high-end technologies which it is more suitable to be implied at modern urban city than somewhere in rural area as it needs more expertise to design the whole system. In the third approach, by using a centralized system to control the water distribution network may not provide higher scalability and robustness when compare to the second approach, but still it can provide a solution that can improve the efficiency of the existing water distribution network and at the same time reducing the operation cost of the water network.

2.2 Process Variables

The function of a water distribution system is to provide water to all residential, commercial and industrial customers at all day and has to fulfil the high demand of water supply from customer daily. It normally comprise of water tanks, pumps, valves, pipelines and sensors.

As discussed in [7], operation systems are based on tank levels, where it can be operated automatically or manually. Operation of the water distribution system is based on three important parameters; pressure, flow rate and tank water levels. Pressure plays an important part itself in a distribution system. During normal condition, it should be kept above 30psi and below 100psi. Pressure that is greater than 100psi, will lead to water wastage as the pipelines at normal residential areas as well as commercial cannot sustain the high pressure. Minimum pressure required is mainly depends on the customer itself, for example customer at a residential area may required level of water pressure which is lower than water level pressure at certain industries such as hospitals. However the most important part is that water level pressure must be maintain at a constant level at anytime. When pressure is not at appropriate level, operators should take corrective actions to remedy the situation. This is where pumps come in to the water distribution system. For instance, when the water pressure in the system became too high, motor pumps will be stopped or closed down to further increase the pressure in the pipeline system. Other than that, their function is to maintain the pressures at acceptable level as well as valves. Measurements of pressure in the system are taken to assist in system operations.

Flow rate of water is another important parameter that is used to control a water system with an acceptable range of flows that is to be dictated by the nature of the water distribution system. Flow rate can be said that is directly related to pressure. When flow rate of water in the pipeline increase, the pressure at the end of the pipeline will decrease. Therefore in water distribution system that operates based on the pressure measurement it can also be said that the water distribution system operates based on the flow rate of water.

In water distribution network, it depends mainly on the pressure itself in the whole system. Reservoir tank is placed above the buffer tank where gravity is able to provide sufficient pressure to maintain the constant flow of water from the output of the reservoir tank

to the buffer tank. Besides that, the reservoir tank is remained open to implement the atmospheric pressure to the water tank. With that, the water that flow out from the water tank can flow with better consistency and at a faster rate.

Another important parameter for the monitoring system stated in the research paper is the water level in system tanks, where most of the operations of water system are based exclusively on it. It provides an indication of the overall pressure throughout the whole system. Let's say when the level of water in the tank is high; the pressure in the system is certainly higher. Therefore operators have to ensure that there are sufficient volume of water is stored in the tank. However, most water distribution systems nowadays are equipped with an extra water tank which acts as a buffer to avoid water shortage during emergency such as source outage.

2.3 Monitoring and Control Technology

Future operations in water distribution systems offers great potential to improve in its monitoring and control technology as well as high technology control in operation system.

For instance, [8] propose a system to monitor and analyze large distribution water system using GUI to create an interface to outline a pattern for the water network alongside with an online data mining engine. This system mainly focuses on real-time summarization and correlation data to get an overview of the spatial pattern of the data for the entire system. In this paper, it stated that in large distribution water system, problems such as real-time monitoring, large input and output data, and water quality occurs often in existing water distribution network which uses traditional method where quality and safety of the water system is an important aspect nowadays. Therefore in order to obtain near real-time analysis, sensors data will be send through online and analyze via GUI interface. When contamination exists in the water system, users will be notified by the alerter in the system to facilitate out the corrective actions.

Another approach, as stated by Donald V.Chase [7], is by monitoring the water system using a human machine interface (HMI) also known as Supervisory Control and Data Acquisition, SCADA. It refers to an industrial control system which is also a combination of

telemetry and data acquisition. Information is collected by SCADA which is then transfer it back to the main control site, to carry out the analysis that is required to maintain the operability of the system. Unlike using GUI stated in [8], the whole system shown is in spatial-correlation pattern whereas interface displayed by the SCADA system on the operator screen shows the whole system exactly in the real-life system including its components such as pumps and water tanks. Besides SCADA can also be referred as a centralized system which control and monitor the entire site. More information can be obtained from the SCADA system such as water tank levels, pump and valve status. During emergency, it can carry out real-time simulation to provide appropriate response.

There are also other researches that used Matlab in order to have optimal monitoring of water distribution system. For instance, [9] proposed a method using Matlab for optimal monitoring of water storage. The objective of this research is to fill up the water tank with filtered water after subsequent water treatment and distribution to a water conveying system using MATLAB. The scope of this system is to reduce the pollutant constrains that exist in the final storage of the water tank and have maximum water mass in the final storage. In order to achieve the objective, contains of pollutant inside the storage must be less than a given limiting amount, therefore continuous monitoring is needed in order to control the quality of water. From this research, it is said that future research can be done by combining water treatment with water distribution network.

Each approach have their own pros and cons, for example monitoring system using GUI may be effective and help improve the operation system in existing water distribution network, but it can only produce near-time analysis for the distribution network which is not as useful during emergency period such as water shortage. Other than that, the interface of the whole system is based mainly on spatial-correlative pattern which need an expertise in Matlab to analyze the operation of it.

2.3.1 Control Strategies

As stated by [10], there are three types of control method that can be used in a water distribution system, namely supervisory control, automatic control and advanced control. Implementing of control strategies in a water distribution depends on the complexity level of the process in the system itself. Supervisory control requires manual operation where a human monitor is required to monitor the system. Decision made is based on the knowledge or experience of the human operator itself.

As for automatic control, instrumentation and control devices are programmed to operate the distribution system without the existence of a human operator. It is normally applied for small water distribution system; however a human operator may be required to remain on standby. Operation of a water distribution system using automatic control will be more efficient than in supervisory control as the whole system will be monitor and controlled by the system itself and there will be less error compared to supervisory control.

In advanced control, it is normally implement at complicated system which relies on artificial intelligence or control logic to control the system. In automatic control, it reduced the cost associated with personnel but with advanced control, reduced cost is more significant through optimized operating schemes.

2.4 System Implementation in SCADA System

SCADA includes collecting information from field instrumentation and transferring it back to the central site, carrying out necessary analysis and then display the information in operator screens. Required controls are then conveyed back to the process. In other words, SCADA is a system that coordinates but does not control the process in real-time [11]. Concept of the system is illustrated in Figure 2.1 as below,