Addis Ababa University

Addis Ababa Institute of Technology

School of Electrical and Computer Engineering

SCADA System for Water Supply Automation: Case Study of Axum Town

By

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Advisor

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Declaration

I declare that, this MSc thesis represents my own work, except where due acknowledgement is made, and that it has not been previously submitted to this university or to any other institution for a degree or other qualification**.**

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This MSc thesis has been submitted for examination with my approval as a university advisor.

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ABSTRACT

Axum has scarce water resource. At present, there are four wells and a dam that are supposed to supply water from aquifer and provide a barrier constructed to hold back water to the public through the water distribution network. However, the pumping stations at these wells and dam along with the distribution network were managed manually by operators in a primitive manner. During peak consumption periods, which may last for weeks, water was not delivered to wide areas and the resources were not distributed evenly to public. Operators tried hard to achieve fairness by manually controlling gate valves along with pumping stations. Therefore, to overcome these problems, a Supervisory Control and Data Acquisition (SCADA) system to be used to manage the water pumping stations in Axum has been designed. Moreover, this thesis introduces a report mechanism by modeling the existing water supply system which controls loss of data and reduces the loss of water. To obtain accurate data analysis, this work was presented using a LabVIEW software simulation. And also, this system is expected to increase customer satisfaction, reduce water distribution cost and provide an accurate overview of the plant's operations. Furthermore, SCADA stores valuable information about the water system performance; and this data is necessary for efficient development of the existent distribution system in a way that met population growth.

Key words: Automation, LabVIEW, SCADA, Solenoid valve, virtual instrument, Water supply system.

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LIST of ABBREVIATIONS and SYMBOLS

ACK	Acknowledgment
ASCII	American Standard Code for Information Interchange
ATWSS	Axum Town Water Supply Service
BP	Booster Pump
CANbus	Controller Area Network bus
CRC	Cyclic Redundancy Check
CWR	Clean Water Reservoir
DAQ	Data Acquisition
DCS	Distributed control system
DP	Decentralized Periphery
EMR	Enda Mikael Reservoir
FPGA	Field Program Ming Gate Array
GSM	Global System for mobile communications
HMI	Human Machine Interface
IED	Intelligent Electronic Devices
IP	Internet Protocol
IT	Information Technology
LabVIEW	Laboratory Virtual Instrumentation Workbench
LAN	Local Area Network
MCR	Main Control Room
MMI	Man Machine Interface

MTU	Master Terminal Unit
NI	National Instrument
NSR	Nigste Saba Reservoir
OLE	Object Linking Embedding
OPC	OLE for Process Control
PA	Process Automation
PC	Personal Computer
PID	Programmable logic controller
PLC	Programmable Logic Controller
PROFIBUS	Process Field Bus
RSF	Ruped Sand Filter
RS	Recommended Standard
RTU	Remote Terminal Unit
SCADA	Supervisory Control &Data Acquisition
SMS	Short Message Send
SP	Submersible Pump
SQL	Structural Query language
SSF	Slow Sand Filter
ST	Sedimentation Tank
TCP	Transmission Communication Protocol
WM	Water Meter
VI	Virtual Instrument

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Water is considered to be a finite global resource [1].Water supply is the provision of sufficient and purified potable water to people by using different system without any interruption. In Axum, the population is around 66,816 and demand for these people is 4008.96 m^3/day whereas the supply is 3272.4 m^3/day [2].

The main sources of water are ground water & surface water located in different parts of the town these are:

1. Mdemar dam (Adwa):2235.6 m^3/day are being supplied (Dam).

2. Water Well One: 475.2 m^3/day is being supplied (Ground).

3. Water Well Two: 216 m^3/day is being supplied (Ground).
4. Water Well Three: 259.2 m^3/day is being supplied (Ground).
5. Water Well Four: 86.4 m^3/day is being supplied (Ground).

The total water supplied is3272.4m^3/day [2].Water supply is provided by public utilities commercial organizations, community endeavors or by individuals, usually via a system of pumps and pipes.

Generally, currently Axum town has

1. Nigste saba reservoir-distributed by two pumps and a gravity to town
2. Enda Mikael reservoir-distributed by gravity to the town (120m^3/hour).

In 2010, about 85% of the global population (6.74 billion people) had access to piped water supply through house connections or to an improved water source through other means such as standpipes, water kiosks, spring supplies and protected wells. However, about 14% (884 million people) did not have access to an improved water source and have to use unprotected wells or springs, canals, lakes or rivers for their water needs.

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Water supply systems get water from a variety of locations after appropriate treatment, including groundwater (aquifers), surface water (lakes and rivers), and the sea through desalination.

The water treatment steps include, in most cases, purification, disinfection through chlorination and sometimes fluoridation. Treated water then either flows by gravity or is pumped to reservoirs, which can be elevated such as water towers or on the ground[3].SCADA is an acronym for Supervisory Control and Data Acquisition and it uses to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining, and transportation[4].

Besides, in my research SCADA system is a helpful tool to utilize the resources that we have in an efficient and effective manner by avoiding leakage of water and monitoring the in-flow water supply from each ground sources and dam source properly into the main distribution center of the town.

1.2. Problem Statement and Motivation

Water supply of Axum Town bureau uses manual recording mechanism to manage the amount of water that supplied to the community. In addition to that, the manual recording system of the water supply has many problems such as human error during entering data, loss of recorded data, and delay in reporting. Besides, demand and supply of water does not match properly.

According Axum Town Water Supply Services, the daily water demand of Axum's residence is 4008.96 m^3/day whereas the actual supply is 2889.3 meter cubic per day. Therefore, the losses of water during pumping station are 383.1 m^3/day and there is high shortage of water in the town due to poor management and inadequate control of wastage. Because of this reason, the people's level of hygiene is low, industrial processes are being interrupted, and the overall daily activities of the people are affected. This leads for the society being poorly served in their health condition and business operations.

In order to solve the aforementioned problems, we will implement an automated system of water supply. Therefore, the needs of having SCADA system water supply is for identifying people's problem easily and for giving feedback within a short period of time by cross checking the amount of water that is produced and distributed to the end users. Also, the new proposed automated system easily notifies the expert of the amount of water wastage that occurs.

1.3. Objective of the Thesis

1.3.1. General Objective

The prime objective of this M.Sc. thesis work is to study, design, evaluate and simulate the automated SCADA system water supply for Axum Town.

1.3.2. Specific Objective

The study in this thesis will address the following specific objectives:

- To assess existing water supply of Axum
- To design and model system layout.
- To simulate HMI of water supply system using SCADA software.
- To evaluate the performance

1.4. Significance of the Study

The thesis has two sided importance. On the first, the SCADA based water supply automated system avoids measurement delay and enables quick control actions to be taken. Therefore, the developed programming can supplement measurement and aids on effective and fast in solved the operation. As a result, it saves time; more accurate quality can be further improved. On the other side, as the first of its kind, it creates motivation on applying SCADA based level sensor to water process industries.

On the other, the study will help the water supply operators to provide a sustainable, reliable, stable and uninterrupted water supply to respected customers through efficient energy management system in an optimal way. It is also possible to automate for the water supply to optimize the scarce water resources for the society and identify potential vulnerabilities and potential solutions. In addition, the findings of this study could also provide useful lessons for water supply system operators regarding the water sector.

1.5. Scope of the Study

The study on this thesis is on supply of water report from different sources located in different places to the distribution center in Axum Town. The performance analysis in this thesis work has been carried out based on the simulation of proposed work using LabVIEW software.

1.6. Methodology

- In order to achieve the main aim of the study, there are various procedural tasks followed by the author. And the following formal methodologies will be followed subjected to changes if need be in the due course of the work.
- Literature Review: The work of this thesis is necessarily based on what has already been done by other scholars related to this selected topic. So as to look into the works of these scholars and get necessary and important information related to the topic; different literatures will be referred from different available sources such as books, papers, journals and articles etc. Therefore, the literature review includes reading books, articles, papers, journals, simulation tools and searching internet related to SCADA based water supply system.
- Data Collection: Due to the fact that the successfulness of this research is determined by the required data, various data will be collected from AWSS and verification of data at the site is performed. This is followed by studying the major problems. And also methods of avoiding this problem based on the system we have will be revised.
- Then study and analysis of the collected data will be undertaken.
- Based on the result of the analysis evaluation and design will be done and simulated using LabVIEW software.
- Then after analyzing the designed system, the whole work of the thesis will be concluded by suggesting implied recommendation on the area.

1.7. Organization of Thesis

This thesis is organized under six chapters which are briefly summarized as shown below. In the first chapter introduction of water supply system has been discussed and also describes statement of the problem, objective, significance, scope and methodology of the research. Chapter2 The description on theoretical background and literature review Chapter 3 Theoretical Background of SCADA and understand the concepts of SCADA system, SCADA system parts, SCADA Protocols, Basics of SCADA System, SCADA System Architecture, Description of LabVIEW software and Operation panels of LabVIEW that was taken by water supply system operators Chapter 4 Design of Automated SCADA control system Chapter 5 Simulation Result and Discussion of the Thesis. Finally, in Chapter6 explains the conclusions and recommendation.

CHAPTER TWO

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.4. SCADA System for Water Supply

The water supply systems are an important part of the infrastructure which must be assured the continuity of the water storage, the water quality and also the distribution of the water supply to the end user. Monitoring and control of the quality, distribution and storage of water supply is essential and very important that the management of this resource must be well organized because of the restrictions imposed by the water availability, hydrological conditions, the storage capacity of the tanks and water towers and the increasing diversity of water use[5].

Sustainability of clean water resource has been a big issue being discuss lately. From the reason of lack of resources to the attitude of end user that frequently waste clean water, the problem seems not having any improvement on finding ways to at least contain it from increasing. The problem is quietly related to poor water allocation and monitoring, inefficient use, wastage and also lack of adequate integrated water management.

There are some reasons that are not controllable such as raw resources and the attitude of end user. But there is an area that we can at least control it to the lowest level possible by applying better technology and management.

The area that can be improved is the monitoring and management of water storage and distribution. Usually we see water pipe leaks that result a fountain of burst water. As a result of this, there will be a water shortage problem because of the pressure lost which prevents the water from being supplied to the storage tanks. By applying the automation system, the management of water distribution and monitoring can be improved. Thus, resulting in reducing the level of water wastage. Using this concept, it will increase the ability in monitoring the usage of treated water and their usage efficiency.

It is important that the water supply level at the storage tank being monitored and measured continuously. Measuring water level is an essential task for government and resident [6].

In the last few years, there are many monitoring system that have been integrated with water level detection system to enable user to monitor and get more information about water supply storage. Common method of level detection is simply to start the pump at low level and allow the pump to continue to pump in water until certain level is reached in the water storage tank.

This method is not adequate to ensure the constant water supply especially during peak consumption by user plus there is no data or information sent to the control person. The system that provides adequate controlling and monitoring aspect usually includes visual information as well as continuous data indication. Audio and visual alarm also being set at a desired level and the control of the pumping system is included as well and the setting is based on the user requirement. Proper monitoring is essential to ensure water sustainability being reached, with disbursement being linked to sensing and automation process. Such an automation system entails water monitoring system using Programmable Logic Controller (PLC) and SCADA.

In order to automate the control of the water supply storage tank and the pump station, there is a need to develop a controlling and monitoring system using Programmable Logic Controller (PLC) and SCADA (Supervisory Control and Data Acquisition).

The PLC will communicate through its input and output to send the data to the monitoring system using SCADA. SCADA system will then process the data and display it to the user using visual and numerical display. All the setting and parameter adjustment, water level monitoring, data acquisition and data logging will be done through SCADA system.

This system will always communicate with PLC to retrieve information, turn On/Off the system and manage the whole process. This system will help reduce error and downtime caused by human negligence. For this Thesis, a controller for controlling the water supply of the Axum town will be designed using LabVIEW and this controller will then be integrated together with PLC as switching device and SCADA as the monitoring and data acquisition device.

2.5. Literature Review

Several works have been done for water supply automation system design using SCADA system in many countries and in Ethiopia, SCADA system is implemented in power, railway, and water supply. However, to cover all the research which is worked by different researchers is very difficult. Therefore, we compiled the most important researches by categorizing into two such as PLC based SCADA, LabVIEW based SCADA system for water supply automation method which are related to my work here.

2.2.1. PLC based SCADA System for Water Supply Automation

In modern industry, PLC based SCADA control systems have been extensively implemented in many applications, such as water supply, water distribution and wastewater treatment control system, Sun-tracking systems, wind energy systems, photo-voltaic applications, heating ventilation and air conditioning (HVAC) control, manufacturing and so on. One common feature of these applications is that they can be modeled as process control problems.

For example, in the water and wastewater treatment control system, the pumps and valves are controlled according to the real time data of the process. To be more specific, water supply control problem is a typical process control problem. Therefore, in this section, some related literature is reviewed and discussed.

In June 2015, Baranidharan T**,** *et al*. [6]:The researchers proposed, "automated water distribution system using PLC and SCADA", to distribute the municipal water equally to all street pipe line and to prevent the drinking water from the theft. Besides, to implement their system accurately they use different equipment's such as level sensor, flow sensor, and solenoid valve and the overall system is connected to PLC using RS-232 cable. However, they did not mention on how they controlled the water level inside the storage tank.

In March 2016, Nasik Mahiravni ,*et al*.[7]: This work entitled with "Automated Water Distribution System for smart city using PLC and SCADA'', to Sustainable of clean water resource we be allocated in water storage and to solve a water shortage problem because of the pressure lost, which prevents the water from being supplied to the storage tank. In order to develop the proposed system they have used solenoid valves, flow sensors, power supply which connected to PLC and supervised using SCADA equipment's. Finally, they conclude applying the automation system known as SCADA with the integration of Fuzzy control is sufficient to control water storage, to improve the management of water distribution and monitoring.

Palkar Prashant**,** *et al*.[8]: The researchers proposed, "Automation in drinking water supply distributed system and testing of water", to automate the water supply which enhances water distribution, reduces wastage of water as well as identify the theft of water. In addition to this the proposed automated urban water supply system consists of PLC, pH sensors, chlorine measurement system, and sensors for water theft detection, GSM module, SCADA system and motor driver. Finally, the researchers conclude that using the proposed system a satisfactory result was achieved and their work is cost effective. Even though, their work was not compared with any related system.

In January 2016, Bambal Suraj, *et al.* [9]: This work entitled with "design & implementation of intelligent water supply management system based on PLC & SCADA'', in order to create a water supply system which will maintain regularity in water supply, equal amount of water supply to every area under system and to detects leakages in supply pipelines, prevents misuses like motor connections in supply line, detects smoke in case of explosive conditions & fulfills water supply demand for the same. Besides, to implement their system accurately they use different equipment's namely level sensors, proximity sensors, smoke and fire sensors, control & safety valves, flow sensor and the overall system is connected to PLC using communication network. Finally, they conclude as they have achieved satisfactory result.

BhawarkarA N.B *et al*.[10]:This work entitled with ''literature review for automated water supply with monitoring the performance system using PLC &SCADA'', to increase population and thus the wide expansion of urban residential areas has increased the need of proper distribution of water. This distribution of water in every house within different areas needs the control and monitoring for preventing the wastage of water and the water theft practices.

Pooja *et al.* (2015) [11]: carried a test on a PLC based single water tank control system using PID controller. In their system, an HMI which is programmed on NI-LabVIEW is connected to an Allen Bradley Micro830 PLC through the Modbus RTU communication protocol.

According to the researchers, this system is designed for training purpose in order to have a complete understanding of PLC based process control system design. In their literature, some necessary modeling is introduced such as the water tank modeling, transducer modeling, and the control valve modeling. Some parameters, such as the resistance of the control valve, and current to pressure (I/P) converter, are estimated depending on the experimental data by using the method of least squares. Furthermore, they applied PID algorithm into the PLC to achieve a better result. The PID parameters are calculated by using Ziegler Nicholas (Z-N) method. Finally, the authors conclude that the experimental result is matched with their prediction.

Furthermore, Pooja Belagali *et al.* (2011) [12]:developed a PLC based PID control system for a water tank control system. In their paper, Reza et al. applied an HMI into the system for advanced monitor and control purpose. Finally, the result shows that the PLC based PID control system works correctly in their design.

2.2.2. LabVIEW based SCADA System for Water Supply Automation

LabVIEW based SCADA system models are summarized as follows:

In August 2014, D. Gajipara Nishantkumar, *et al*.[13]:This work entitled with "Design of SCADA for real time system with LabVIEW and Microcontroller'', to describe the observation and construction of a microcontroller (PIC16) and LabVIEW based SCADA system for monitoring & accessing the performance by acquiring and controlling the physical parameters such as temperature, Humidity, Soil moisture and intensity of light of greenhouse system on a real time basis. In addition to this they use the difference equipment's such as temperature sensors, Lighting sensors, humidity sensor, moisture sensors, LCD display driver all are connected to PIC16F877A using recommended standard 232 cables. Finally, they conclude the proposed technique is more efficient for water supply automation.

In Number 2017, Vishal.S, *et al.*[15]: The researchers proposed, "Smart water supply using LabVIEW and Arduino.This project is mainly drafted in order to supply water regularly for the localities and concentrates on cleaning the water and removing the contaminants and distributing the water evenly to the people. It's also added with additional monitoring the water level inside the tank and notification. Besides, to implement their system accurately they use the difference equipment's, such as flow sensor, solenoid valve, turbidity sensor, transmitter, receiver, level sensor, solenoid valve, supply pump, drain pump, and the overall system is connected to Arduino using the transmitter and receiver. Therefore, using the new proposed model they achieve better satisfactory a solution for a long lasting problem and their work is cost effective and efficient in contrast with the existing model provides water to all localities without controlling the amount water being supplied.

In Jun 2015[16, 17]: The researcher proposed that "Design and Implementation of LabVIEW based SCADA for Textile Mills''to addresses the need of factory automation within the scope of machine control for small scale textile industries. The project presents the design of LabVIEW based SCADA system for centralized control. It makes use of PLC as a field controller to operate the prototype design of Stenter Machine, widely used in textile industries. The PLC controller and the LabVIEW based SCADA are communicating through the RS-232 link. Finally, the researcher got cost efficient and reliable solution for automation of small scale industries. But they could not compare with others.

CHAPTER THREE

3. THEORETICAL BACKGROUND OF SCADA

3.1. Introduction

Control engineering theory studies systems performance stability that must certain specification. The ideal simple system consists of an input, plant, and output. This system may be an open loop which has no feedback signal as shown in Figure (3.1), or a closed loop, similar to open loop with added feedback signal as shown in Figure (3.2) [18].

SCADA system is considered a closed loop system. This chapter talks about SCADA systems its, Definition, SCADA system parts, SCADA Protocols, Basics of SCADA System, SCADA system architecture, hardware architecture, software architecture, description of LabVIEW software and most applications.

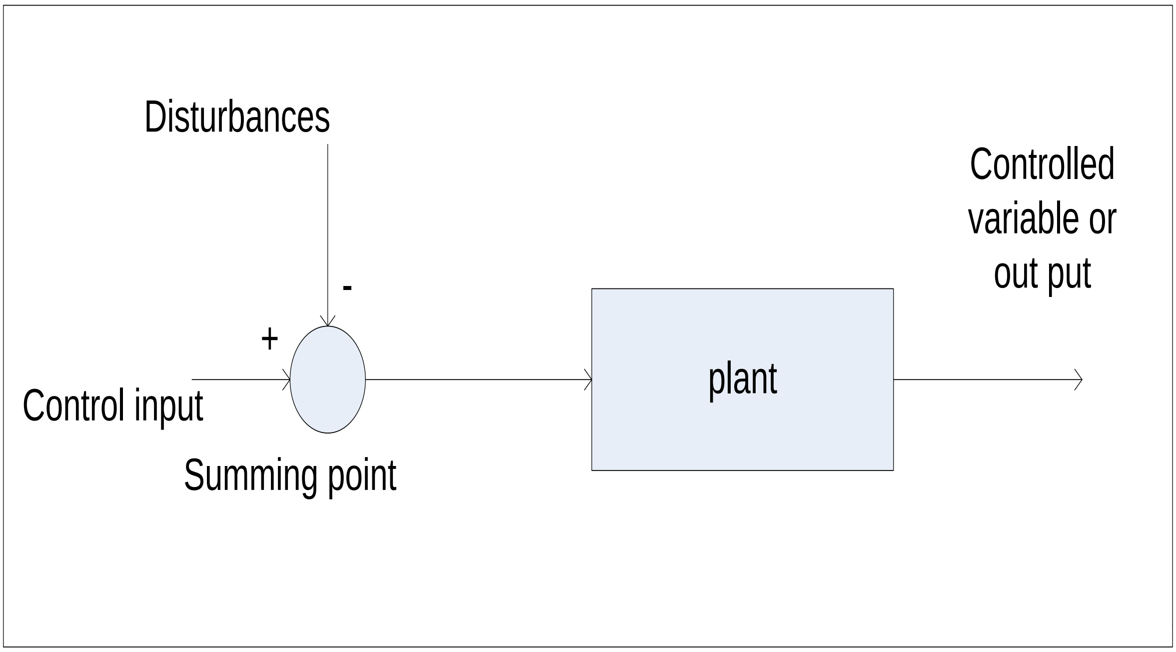

Figure 3.1 Open Loop System

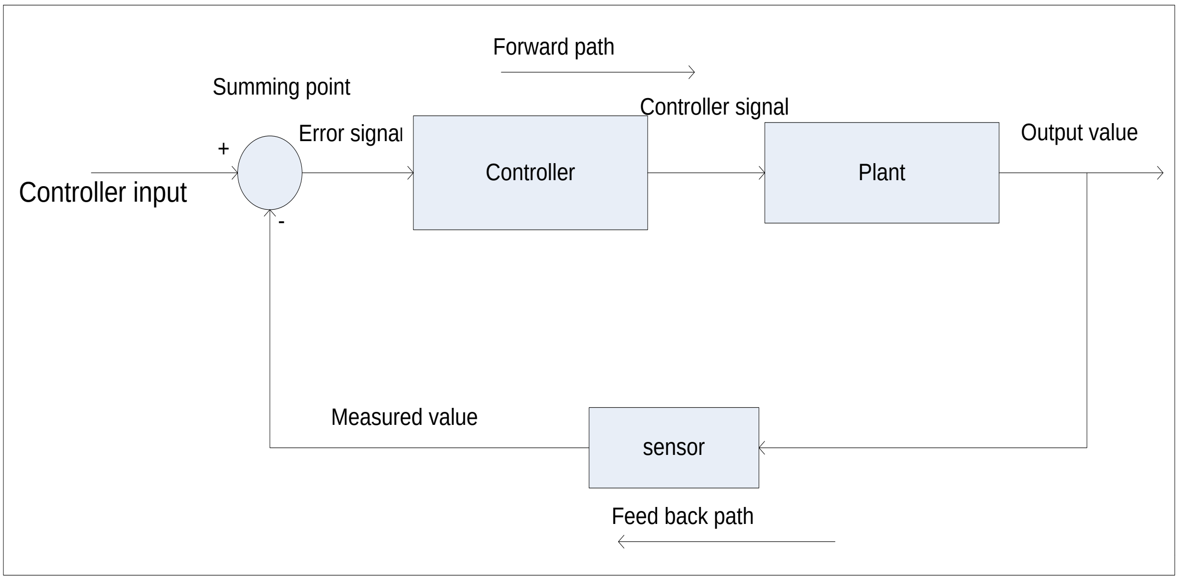

Figure 3.2 Closed Loop System

3.2. Automated System Control versus Conventional System Control

The automated control has much distinguishing benefits over the conventional control advancing into new level of water supply and water distribution. The aspect of handling uncertainties, failure prediction and automatic system control makes water restoration easier.

Renewable sources are also to be utilized judiciously. Hence there is a need to optimize the energy use and reduce waste. Automation of water supply systems is a solution toward this goal, and every sector of the water network system, from well water and dam, to reservoirs and also to the customer is being automated today to achieve optimal use of satisfaction. The automated control system answers the question of water supply system wastes, which are the concern of this thesis, with high priority automatic monitoring, coordinating and operating the distribution, supply and network components in a real-time mode from remote locations. It can automatically perform the fault detection and service restoration activities without an intervention of operators. It can also identify the fault location and assist the control center operators and the repair crews during the fault management activities.

In general, SCADA based automated system have many advantages over traditional way of control, among them:

❖ Reduced human influence and errors, as the values are accessed automatically, and the meter reading and related errors are avoided.

- Gives fast response to disturbance.
- Increased reliability.
- Lower operating costs, as there is less personnel involvement due to automation.
- Faster decision making, as a wealth of information is made available to the operator about the field site (system).

3.3. SCADA System

SCADA stands for Supervisory control and data acquisition systems are vital components of most nations' critical infrastructures. The supervisory control and data acquisition (SCADA) system is the backbone of modern industry. It provides centralized control and monitoring of processes with data logging. Most popular SCADA system applications founded in water treatments, chimerical plant, and power networks[19]. SCADA Systems became popular in the 1960's and arose to more efficiently monitor and control the state of remote equipment [20].

SCADA provides management and monitoring with real-time data on production operations, implement more efficient control paradigms, improves plant and personnel safety, and reduces costs of operation. These benefits are made possible by the use of standard hardware and software in SCADA systems combined with improved communication protocols and increased connectivity to outside networks, including the Internet. However, these benefits are acquired at the price of increased vulnerability to attacks or erroneous actions from a variety of external and internal sources [21].

It is also a software package installed on networked computing platforms, like personal computers (PCs) or small-dedicated devices, which are hardened for industrial environments [22]. SCADA provides a high-level layer on top of the Programmable Logic Controllers (PLCs) [23],[24] 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 (3.3).

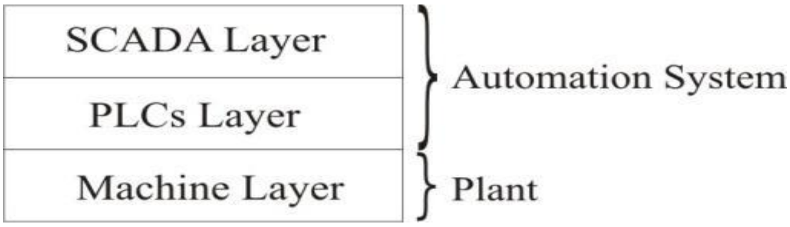

Figure 3.3 Functional decomposition of an automation system

3.4. SCADA System Evolution, Definitions, and Basic Structure

Supervisory control and data acquisition (SCADA) means different things to different people, depending on their backgrounds and perspectives. Therefore, it is important to review the evolution of SCADA and its definition as understood by professionals and practitioners in the field. Listed here are two typical definitions of a SCADA system:

- ❖ SCADA is the technology that enables a user to collect data from one or more distant facilities and/or send limited control instructions to those facilities.
- ❖ SCADA is a system operating with coded signals over communication channels and provides control of RTU (Remote Terminal Unit) equipment.

Additional definitions associated with SCADA systems are given in Table (3.1).This list is not meant to be all-inclusive, but describes some important terms used in the application of SCADA systems[24].

Table 3.1 SCADA-Related Definitions

Term	Definition
Deterministic	Degree to which an activity can be performed with in a predictable time frame.
Proportional ,Integral, Derivative(PID) Control	Method used to calculate control parameters to maintain a predetermined set point. Mathematical techniques are used to calculate rates of change, time delays.
Real-time	An action that occurs at the same rate as actual time; no lag time, no processing.
Real-time operating system (RTOS)	A computer operating system implements process and services in a deterministic manner.
Hot stand-by system	A duplicate system that is kept in synchronism.

The main process of SCADA system is described in three hierarchical processes first from the top: Supervisory process, the second Control process, and finally Data Acquisition process. Figure (3.4) illustrates these processes.

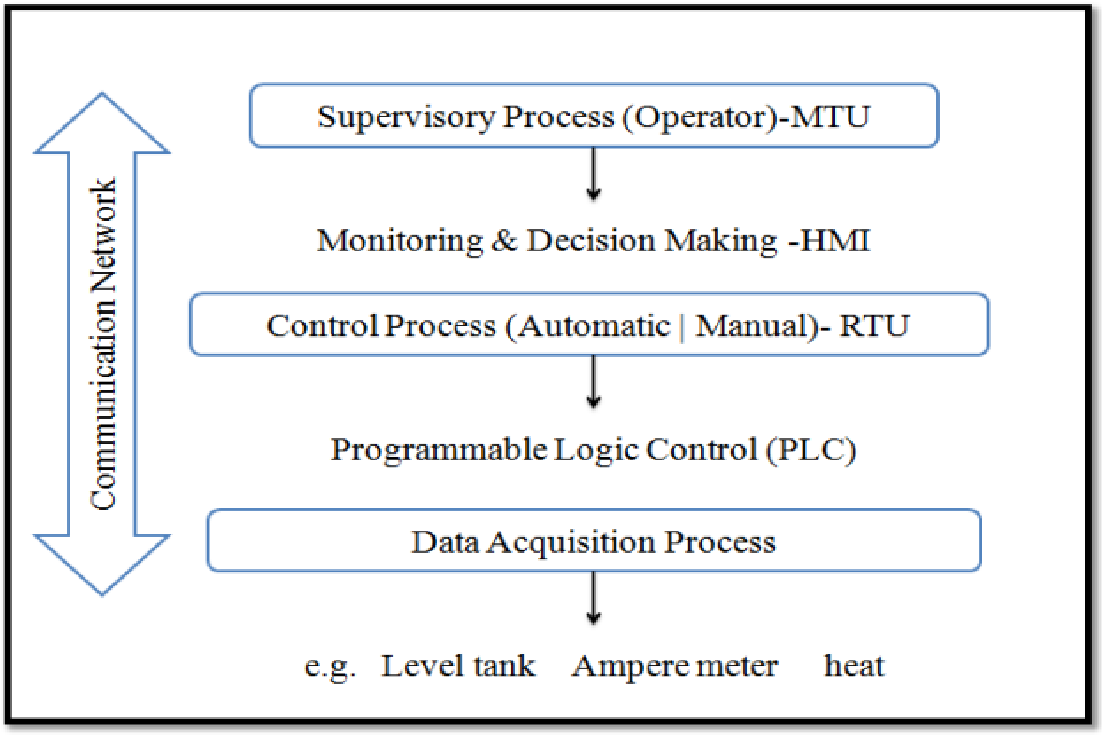

Figure 3.4 SCADA System Structure

3.5. SCADA System Parts

SCADA systems can be defined by its main parts that are:

1. One or more field data interface devices, usually RTUs, or PLCs, which interface to field sensing devices, local control switchboxes, and valve actuators.

2. A communications system used to transfer data between field data interface devices and control units and the computers in the SCADA central host. The system can be radio, telephone, cable, satellite, etc., or any combination of these.

3. A central host computer server or servers (sometimes called a SCADA Center, master station, Master Terminal Unit (MTU) or Main Control Room (MCR)).

4. A collection of standard and/or custom software (sometimes called Human Machine Interface (HMI) software or Man Machine Interface (MMI) software) systems used to provide the SCADA central host and operator terminal application, support the communications system, and monitor and control remotely located field data interface devices.

3.5.1. Master Terminal Unit (MTU)

At the heart of the system is the master terminal unit. The master terminal unit initiates all communication, gathers data, stores information, sends information to other systems, and interfaces with operators. The major difference between the MTU and RTU is that the MTU initiates virtually all communications between the two. The MTU also communicates with other peripheral devices in the facility like monitors, printers, and other information systems. The primary interface to the operator is the monitor or CRT that portrays a representation of valves, pumps, etc. As incoming data changes, the screen is updated.

3.5.2. Remote Terminal Unit (RTU)

Remote terminal units gather information from their remote site from various input devices, like valves, pumps, alarms, meters, etc. Essentially, data is either analog (real numbers), digital, or pulse data (e.g., counting the revolutions of a meter). Many remote terminal units hold the information gathered in their memory and wait for a request from the MTU to transmit the data. Other more sophisticated remote terminal units have microcomputers and programmable logic controllers (PLC) that can perform direct control over a remote site without the direction of the MTU. In addition, PLCs can be modular and expandable for the purpose of monitoring and controlling additional field devices. Within the RTU is the central processing unit (CPU) that receives a data stream from the protocol that the communication equipment uses. The protocol can be open like Modbus, Transmission Control Protocol and Internet Protocol (TCP/IP) or a proprietary closed protocol. When the RTU sees its node address embedded in the protocol, data is interpreted and the CPU directs the specified action to take.

3.5.3. Communications Equipment

Communication equipment is required for bi-directional communications between an RTU and the MTU. This can be done through public transmission media or atmospheric means. Note that it is quite possible that systems employ more than one means to communicate to remote sites. SCADA systems are capable of communicating using a wide variety of media such as fiber optics, dial-up, or dedicated voice grade telephone lines, or radio.

3.5.4. SCADA Software

There are many software packages in today's information technology (IT) market which enables engineers with moderate programming experience to build SCADA [30]SCADA server applications handle data archiving, alarm processing and events logging. Main parts of the SCADA system are the device driver (PLC/RTU drivers) and the database servers [31]. Object Linking Embedding (OLE) for Process Control (OPC) [32] is an open standard designed to bridge process control hardware and software applications.

An OPC server is simply a PLC device driver which enables programmers to communicate with the PLC through a standard interface. SQL server from Microsoft Company is widely used for data archiving, alarm processing and events logging. SMTP server from Microsoft Company may be used to build email and SMS alarm messages to alert the operators about unacknowledged alarm events happened for longer time than adjustable set delay time. SCADA systems include a HMI, which uses graphical interface to visualize the state system variables, change set points, alerts operators of critical condition and generate data trends. As we mentioned before, SCADA software is one of the main parts of the SCADA system. There are several software packages used for designing HMI and SCADA. WINCC from SIEMENS, Cimplicity HMI from General Electric, LabVIEW 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.

3.5.4.1. Human Machine Interface (HMI)

SCADA system includes a user interface, usually called Human machine Interface (HMI). The HMI of a SCADA system is where data is processed and presented to be viewed and monitored by human operator. This interface usually includes controls where the individual can interface with the SCADA system. HMI's are an easy way to standardize the facilitation of monitoring multiple RTUs or PLCs. RTUs or PLCs runs a preprogrammed process and spreads out over the system so monitoring each of them individually may be difficult. Also, RTUs and PLCs have no standardized method to display or present data to the operator, the SCADA system communicate with the PLCs through the system network and processes information that is easily disseminated by the HMI. HMI's can also be linked to database, which can use data gathered from PLC 's or RTU 's to provide graphs of trends, logistic information, schematics for specific sensor or machine or even make troubleshooting guides accessible. In the last decade, practically all SCADA systems include an integrated HMI and PLC device making it extremely easy to run and monitor a SCADA system.

3.5.4.2. OPC Server

OPC stands for OLE for Process Controls and the industrial applications of Microsoft‘s OLE technology that comes with every Windows operating system. The OPC designers put forth the goal of developing a single client/server specification that would allow any vendor to develop software and applications that could share data in a fast, robust fashion, and do it in a way that would eliminate the proprietary schemes that forced these same vendors to duplicate development efforts.

The OPC designers developed the first specification called Data Access Specification 1.0a that was released in early 1996. Using this specification, vendors were able to quickly develop client server software. A major goal of the OPC designers and the Data Access specification was to eliminate the need of client application vendors to develop their own proprietary set of 16 communications drivers. For many vendors, the effort required to develop numerous communications drivers outweighed the development effort involved in the client application itself. With the adoption of OPC technology, a vendor could now focus their efforts almost exclusively on the development of the client application.

The Data Access specification defines how both the client and the server application interface must be constructed. If the specification is followed properly, a client vendor knows that any OPC server that exists for an industrial device can provide the connectivity needed for data access. Issues like time to market or reliability no longer restrict applications to which any OPC compatible application can address. OPC has given the end user the additional benefit of being able to select the best of breed software to solve application problems.

Historically, if the application software did not have the desired communication driver or if the available driver didn't perform adequately, the only solution was to try to persuade the application vendor to either develop the desired driver or repair an existing driver. The time required in either of these cases was usually never short. With OPC, the end user is no longer tied to the resource limitations of the client application vendor.

The user can now choose from a variety of OPC server vendors to address a new driver requirement or remedy a performance issue. Equally, the client application vendor can now focus on the continued improvement of their core product without the disruptive effort required to address communication issues and needs. Our goal within the OPC environment is to be a leading provider of the server component of the OPC equation and to do so by providing a product that is reliable and easy to use. This server is built upon years of development efforts in communications driver development and OPC technology [25] Database Server.

SCADA Database servers are one of most important software used by SCADA system. Any of the database servers used to store and implement data as SQL server, SQL Server Desktop, Access and Oracle. The traditional database servers used in SCADA systems is SQL server from Microsoft Company. OPC servers deal with database servers in managing SCADA system data, which includes Data Logging archiving, paging, alarm and authentication. All system data is stored in the database server. Then it is managed by the SCADA system designer to display the data to the operator simply and quickly using different ways of data management as alarms, SMS messages and reports. In the SCADA, OPC allows multiple applications to simultaneously access the SCADA communications system. The OPC specification is maintained by an independent interested body called the OPC foundation. It is made up of over 200 manufacturers and other interested organizations. For the SCADA, there are two parts to an OPC system.

The first is the OPC server. There are number of Modbus OPC servers available depending on the functionality required. It is the OPC server‘s responsibility to send/receive data from the SCADA system.

The second part is the clients. Typical clients are host systems such as wondeware, FIX or Factory Link, as well as spreadsheets, database, or applications running Visual Basic C++. Also, manufacturers can add additional clients which allow for remote firmware changes and program editors. In this manner, OPC allows a manufacturer's programming tools to simultaneously communicate through the OPC server with an RTU that is being programmed while a host is also communicating with the balance of the RTUs in the field. It should be noted that the OPC server manages the communications network, and as such, while it appears simultaneous, only one message goes at a time. The more correct description would be multiplexing messages. However, considering municipal systems react in terms of minutes or hours, a small slowdown in the system performance to maintain a system in quite justified.

3.6. SCADA Protocols

The important part of any complex SCADA system design is involved in matching the protocol and communication parameters between connecting devices. There are about 200 such real time user layer and application protocols. These include proprietary and non-proprietary protocols, some of which are listed below [33].

- ❖ Modbus RTU / ASCII
- ❖ PROFIBUS Omron
- ❖ CANbus Siemens Sinuate
- ❖ Mitsubishi
- ❖ Other Vendor Protocols

The industry is now moving away from many of the old and proprietary protocols. The following RTU/PLC protocols are emerging as virtual standards in modern SCADA systems.

3.6.1. Modbus

Modbus is one of most important protocols used by SCADA system; it has its roots in the late seventies of the previous century by Modicon PLC manufacturer. It is an open standard that described the messaging structure. The physical layer of the Modbus interface was free to choose. The original Modbus interface ran on RS232, but later Modbus implementations used RS485 because it allowed longer distances, higher speeds and the possibility of a true multi-drop network. In a short time hundreds of vendors implemented the Modbus messaging system in their devices and Modbus became the defacto standard for industrial communication networks [34]. The nice thing of the Modbus standard is the flexibility, but at the same times the easy implementation of it. Not only intelligent devices like microcontrollers, PLCs etc. are able to communicate with Modbus, also many intelligent sensors are equipped with a Modbus interface to send their data to host systems.

Modbus message structure*:* The Modbus communication interface is built around messages. The format of these Modbus messages is independent of the type of physical interface used. The same protocol can be used regardless of the connection type. Because of this, Modbus gives the possibility to easily upgrade the hardware structure of an industrial network, without the need for large changes in the software. A device can also communicate with several Modbus nodes at once, even if they are connected with different interface types, without the need to use a different protocol for every connection. On simple interfaces like RS485 or RS232, the Modbus messages are sent in plain form over the network.

In this case the network is dedicated to Modbus. Although the main Modbus message structure is peer-to-peer, Modbus is able to function on both point-to-point and multi drop networks. Each Modbus message has the same structure. Four basic elements are present in each message as shown in Table (3.2). The sequence of these elements is the same for all messages, to make it easy to parse the content of the Modbus message.

A conversation is always started by a master in the Modbus network. A Modbus master sends a message and depending of the contents of the message a slave takes action and responds to it. There can be more masters in a Modbus network. Addressing in the message header is used to define which device should respond to a message. All other nodes on the Modbus network ignore the message if the address field doesn‘t match their own address.

Table 3.2 Modbus Message Structure

Device address	Address of the receiver
Function code	Code defining message type
Data	Data block with additional information
Error check	Numeric check value to test for communication errors

Modbus serial transmission modes: Modbus/ASCII and Modbus/RTU: Serial Modbus connections can use two basic transmission modes, ASCII or RTU, remote terminal unit. The transmission mode in serial communications defines the way the Modbus messages are coded. With Modbus/ASCII, the messages are in a readable ASCII format. The Modbus/RTU format uses binary coding which makes the message unreadable when monitoring, but reduces the size of each message which allows for more data exchange in the same time span. All nodes on one Modbus network segment must use the same serial transmission mode. A device configured to use Modbus/ASCII cannot understand messages in Modbus/RTU and vice versa.

When using Modbus/ASCII, all messages are coded in hexadecimal values, represented with readable ASCII characters. Only the characters 0…9 and A…F are used for coding. For every byte of information, two communication-bytes are needed, because every communication-byte can only define 4 bits in the hexadecimal system. With Modbus/RTU the data is exchanged in a binary format, where each byte of information is coded in one communication-byte.

3.6.2. PROFIBUS

ROFIBUS (Process Field BUS) [35] is a well-proven, widely accepted open fieldbus standard, which is supported by an industry supplying a wide range of equipment, tools and support. PROFIBUS was introduced in 1989 as German standard DIN 19245, later adopted as International Standard EN 50170.The PROFIBUS standard is now incorporated into IEC 61158, the international fieldbus standard.

The PROFIBUS Family: The PROFIBUS family consists of three compatible version offering very high integrity and a capability appropriate to the need.

- DP-Decentralized Periphery
- PROFIBUS-FMS Fieldbus Message Specification
- PROFIBUS PA – Process Automation

All three systems can operate together; DP and FMS share the same electrical transmission system (RS485), PA uses a different electrical transmission system (IEC1158-2) but shares the same protocol as DP and FMS. PROFIBUS DP extensions and the integration of PROFIBUS with Ethernet technology (PROFINet) mean that FMS is less important than in the past. FMS is no longer supported by PROFIBUS International, however there are still FMS installations successfully operating.

Areas of applicability: Because of the compatible versions, PROFIBUS is applicable to a wide range of applications:

- Simple low-cost distributed control and automation.
- High-speed, time-critical applications.
- Expensive/complex communication tasks.
- Operation in hazardous environments.

Recent developments mean that PROFIBUS is also applicable to:

- High reliability, safety critical systems (PROFISafe)
- Integration with management IT systems (PROFINet).

3.6.3. CANbus

The CANbus (Controller Area Network bus) standard is part of the Device net standard. Integrated circuits are now sold by many of the major vendors (Motorola, Intel, etc.) that support some, or all, of the standard on a single chip. This section will discuss many of the technical details of the standard.

CANbus covers the first two layers of the OSI (Open System Interconnection) model. The network has a bus topology and uses bit wise resolution for collisions on the network (i.e., the lower the network identifier, the higher the priority for sending). A data frame is shown in Figure (3.5) [36].The frame is like a long serial byte. It begins with a start bit. This is then followed with a message identifier.

For Device net this is a 5 bit address code (for up to 64 nodes) and a 6 bit command code. The Ready to receive its bit will be set by the receiving machine. (Note: both the sender and listener share the same wire.) If the receiving machine does not set this bit the remainder of the message is aborted, and the message is resent later. While sending the first few bits, the sender monitors the bits to ensure that the bits send are heard the same way. If the bits do not agree, then another node on the network has tried to write a message at the same time - there was a collision.

The two devices then wait a period of time, based on their identifier and then start to resend. The second node will then detect the message and wait until it is done. The next 6 bits indicate the number of bytes to be sent, from 0 to 8. This is followed by two sets of bits for CRC (Cyclic Redundancy Check) error checking, this is a checksum of earlier bits. The next bit ACK slot is set by the receiving node if the data was received correctly. If there was a CRC error this bit would not be set, and the message would be resent. The remaining bits end the transmission.

The end of frame bits is equivalent to stop bits. There must be a delay of at least 3 bits before the next message begins.

1 bit	start of frame	
11 bits	identifier	arbitration field
1 bit	ready to receive it	
6 bits	control field - contains number of data bytes	
0-8 bytes	data - the information to be passed	
15 bits	CRC sequence	
1 bit	CRC delimiter	
1 bit	ACK slot - other listeners turn this on to indicate frame received	
1 bit	ACK delimiter	
7 bits	end of frame	
>= 3 bits	delay before next frame	

Figure 3.5 CANbus Frame

3.7. Basics of SCADA System

SCADA systems are highly distributed systems used to control geographically dispersed assets, often scattered over thousands of square kilometers, where centralized data acquisition and control are critical to system operation. They are used in distribution systems such as water distribution and waste water collection systems, oil and gas pipelines, electrical power grids, and railway transportation systems. A SCADA control center performs centralized monitoring and control for field sites over long distance communications networks, including monitoring alarms and processing status data. Based on information received from remote stations, automated or operator-driven supervisory commands can be pushed to remote station control devices, which are often referred to as field devices. Field devices control local operations such as opening and closing valves and breakers, collecting data from sensor systems, and monitoring the local environment for alarm conditions [37].

SCADA systems integrate data acquisition systems with data transmission systems and HMI software to provide a centralized monitoring and control system for numerous process inputs and outputs. SCADA systems are designed to collect field information, transfer it to a central computer facility, and display the information to the operator graphically or textually, thereby allowing the operator to monitor or control an entire system from a central location in real time. Based on the sophistication and setup of the individual system, control of any individual system, operation, or task can be automatic, or it can be performed by operator commands.

3.8. SCADA System Architecture

SCADA systems consist of both hardware and software. Typical hardware includes an MTU (Master Terminal Unit) placed at a control center, communications equipment (e.g., radio, telephone line, cable, or satellite), and one or more geographically distributed field sites consisting of either an RTU or a PLC, which controls actuators and/or monitors sensors. The MTU stores and processes the information from RTU inputs and outputs, while the RTU or PLC controls the local process. The communications hardware allows the transfer of information and data back and forth between the MTU and the RTUs or PLCs.

The software is programmed to tell the system what and when to monitor, what parameter ranges are acceptable, and what response to initiate when parameters go outside acceptable values. An IED, such as a protective relay, may communicate directly to the SCADA master station, or a local RTU may poll the IEDs to collect the data and pass it to the SCADA master station. IEDs provide a direct interface to control and monitor equipments and sensors.IEDs may be directly polled and controlled by the SCADA master station and in most cases have local programming that allows for the IED to act without direct instructions from the SCADA control center. SCADA systems are usually designed to be fault-tolerant systems with significant redundancy built into the system architecture.

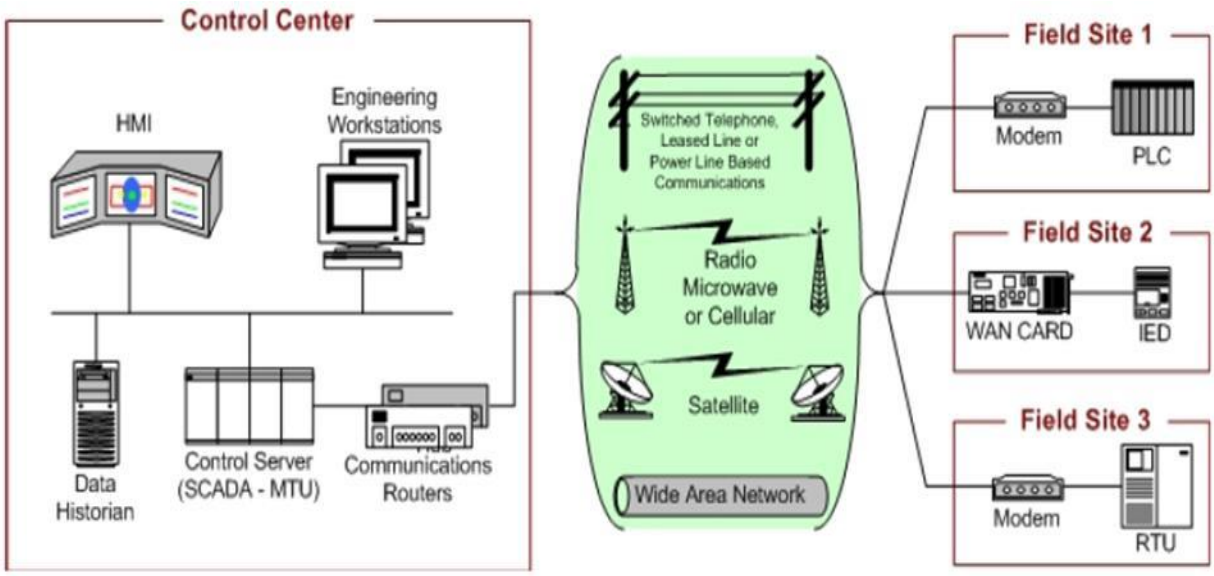

Figure 3.6 SCADA System General Layout [14]

3.9. Description of LabVIEW Software

LabVIEW is an abbreviation for Laboratory Virtual Instrument Engineering Workbench designed by Doctors James Truchard and Jeff Kodosky, founders of National Instrument (NI) Company, and their friend Jack McRiessen. It was first applied on the original Macintosh computer in May, 1986, which even predated the graphic operating system Windows launched by Microsoft. The program LabVIEW developed by NI Company consists of three major functional parts: functional operation and graphic display of virtual instrument; design and edit of background programs; selection and connection of subprograms [38].

LabVIEW is graphical programming language:

- Very different from traditional programming like VB, C#, Maple (is a symbolic numeric computing environment and is also a multiparadigm programming language), MATLAB, Math Script, etc.
- It is more like a “drawing program” than a Programming Language.
- This makes it easy to use for those who are not programmers (or don’t like programming)
- Excellent tool when using Hardware, when you need to take measurements (DAQ), etc.
- It is fun and makes you very creative!

LabVIEW software is realized by the following three modules:

3.9.1. Front Panel

Front panel is a tremendously important part of virtual instrument. No matter the software operations, input, output, or results. All of these depend on the virtual graphical interfaces of the front panel, which make real interactions between computers and users possible.

3.9.2. Flowchart

Flowchart, which is the back panel of the program, realizes the function design of the software. It includes control signal acquisition, overall architecture of the software, calculations and so on. By editing the program of the back panel, the program icons of the back panel are corresponding to the control program of the front panel. Only some built-in functions and program frames are running in the background independently.

3.9.3. Icons and Connectors

If the program in LabVIEW is too complex, the master program will be modularized into several subprograms to command different functions. The subprograms are named as subordinate VI as well which are represented by icons that can be used by the master program with connectors.

3.10. Operation Panels of LabVIEW

In order to make the operations of users more convenient, LabVIEW provides three different sets of operating panels which appropriately classify different types of functional modules. Users can conveniently choose any of the three in their own needs, which include:

3.10.1. Tools Palette

As shown in Figure (3.7), the tools palette provides adjustment and modification tools for LabVIEW including icon lead selection, program debugging, text control, front panel color modification and so on. After users click one of the functions icons, the mouse pointer will turn into that icon which means the corresponding function will be activated. To choose any function in the tools palette by using a default choice is also available [39].

Figure 3.7 Tools Palette of LabVIEW

If the mouse pointer stops over the subprograms or the icons of the back panel, the corresponding tooltip window will appear.

3.10.2. Controls Palette

As shown in Figure (3.8), the control palette consists of the following subordinate palettes.

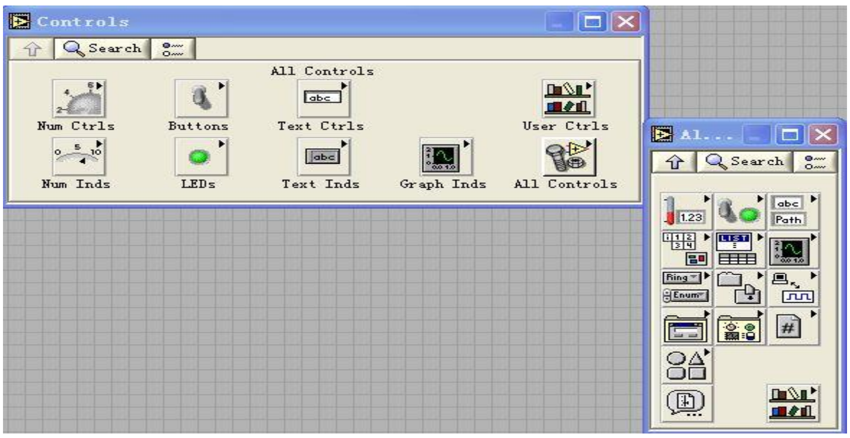

Figure 3.8 Control Palette of LabVIEW

This palette mainly adds various virtual control switches and VIO to the front panel. Users can not only add suitable virtual control icons according to different targets and accuracies of the design programs, but also beautify interactive interfaces by using this palette.

3.10.3. Functions Palette

The functions palette is a tool to set up the flowchart program, as shown in Figure 3.17. Each top-layer icon on the palette represents a subordinate palette. The functions palette includes all important program function modules. It includes the basic operations module, signal processing module and hardware interaction module [40]. It is shown as Figure (3.9).

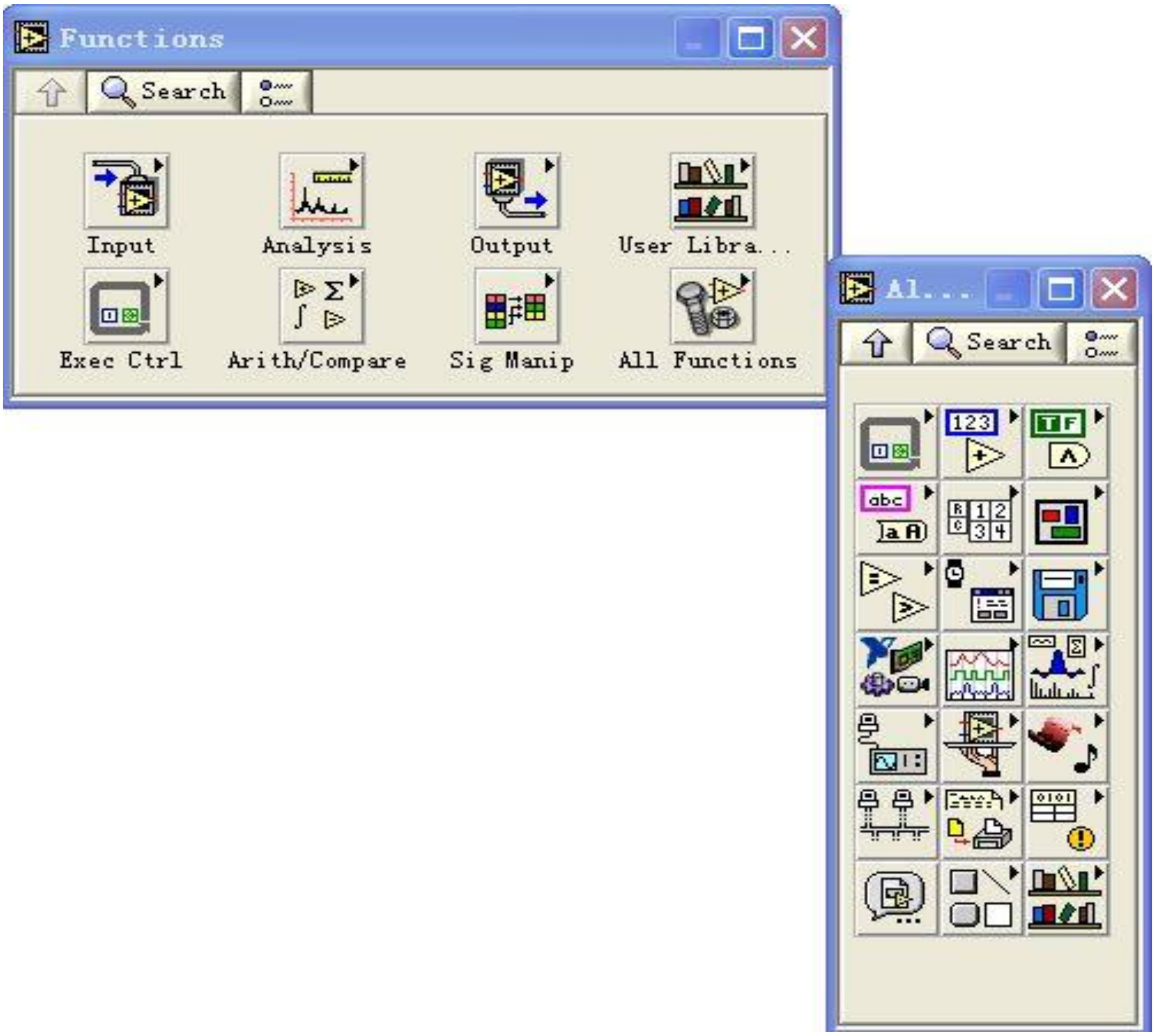

Figure 3.9 Functions Palette of LabVIEW

CHAPTER FOUR

4. DESIGN of AUTOMATED SCADA CONTROL SYSTEM

4.1. Design Procedure

First of all, the required materials namely water sources, pumping elements, pipe networks, flow control, distributes and reservoir were prepared. This water supply system was obtained from two directions water sources. The first water source was come from well sources and the second water source which was come from the dam. After that, they were interconnected to each other as follows: Well water source→pumping→pipenetwork→gate valve (flow control)→MayAbakat chamber reservoir-from this using Booster pump pumps into Nigste Saba reservoir then next into the main center by using booster pump. The second phase Dam watersource→pumping→pipenetwork→gatevalve (flow control)→Adwa collection chamber reservoir→Boosterpump→LakiaReservoir→Boosterpump→EndaEyesusReservior→Booster pump→Enda Mikael reservoir then next into the main center by using booster pump.

Generally, the design of Axum Town water supply system had designed in two different procedures and the procedures would be as follow:

1. Water well sources→submersible pump→solenoid valve→Mayabakat reservoir→booster pump→solenoid valve→Nigste Saba reservoir→booster pump→solenoidvalve→Main reservoir (SCADA system center) which were shown in figure 4.1.

2. Water Dam source→submersible pump→solenoid valve→Sedimentation tank (Adwa reservoir)→booster pump→solenoid-valve→RupedSand Filter (Lakia reservoir)→booster pump→solenoid-valve→SlowSand Filter (Enda Eyesus reservoir)→booster pump→solenoid-valve→CleanWater Reservoir (EndMikael reservoir)→booster pump→solenoid valve→Main reservoir (SCADA system center) which were Shown in figure 4.2. Finally, the general proposed block diagram of SCADA system for water supply automation design system would be as shown in figure 4.3.

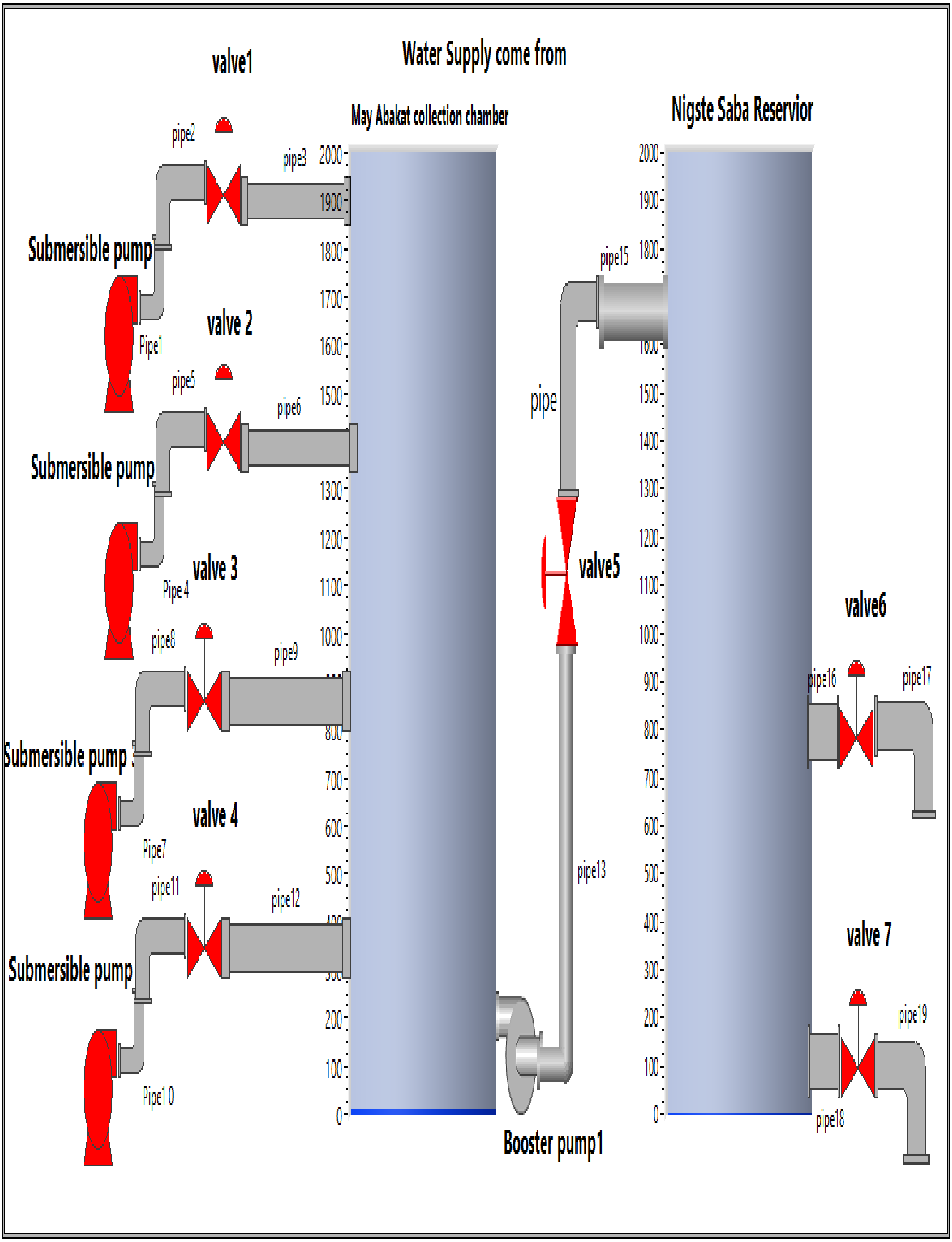

Figure 4.1 water supply comes from well sources

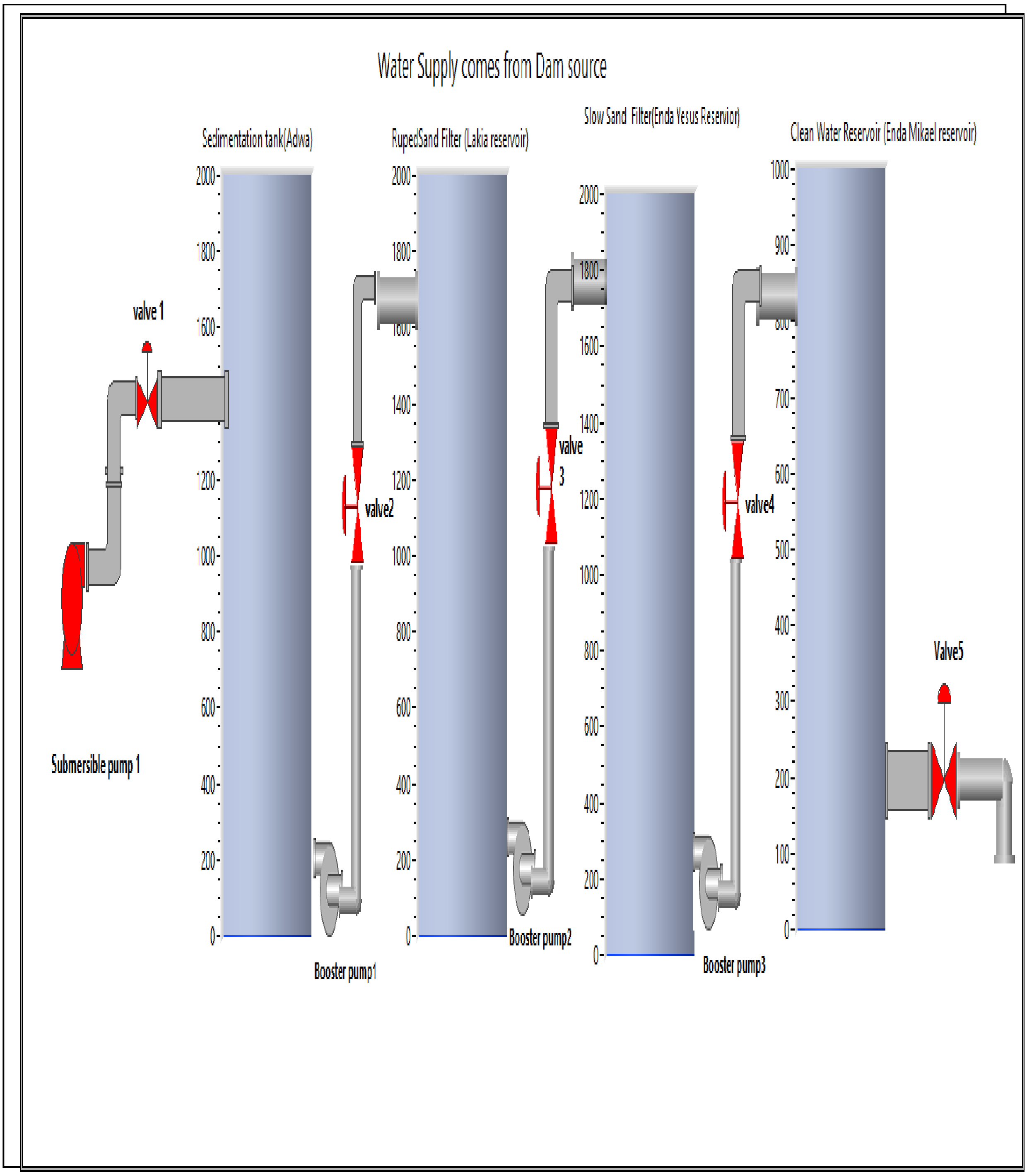

Figure 4.2 Water supply comes from Dam source

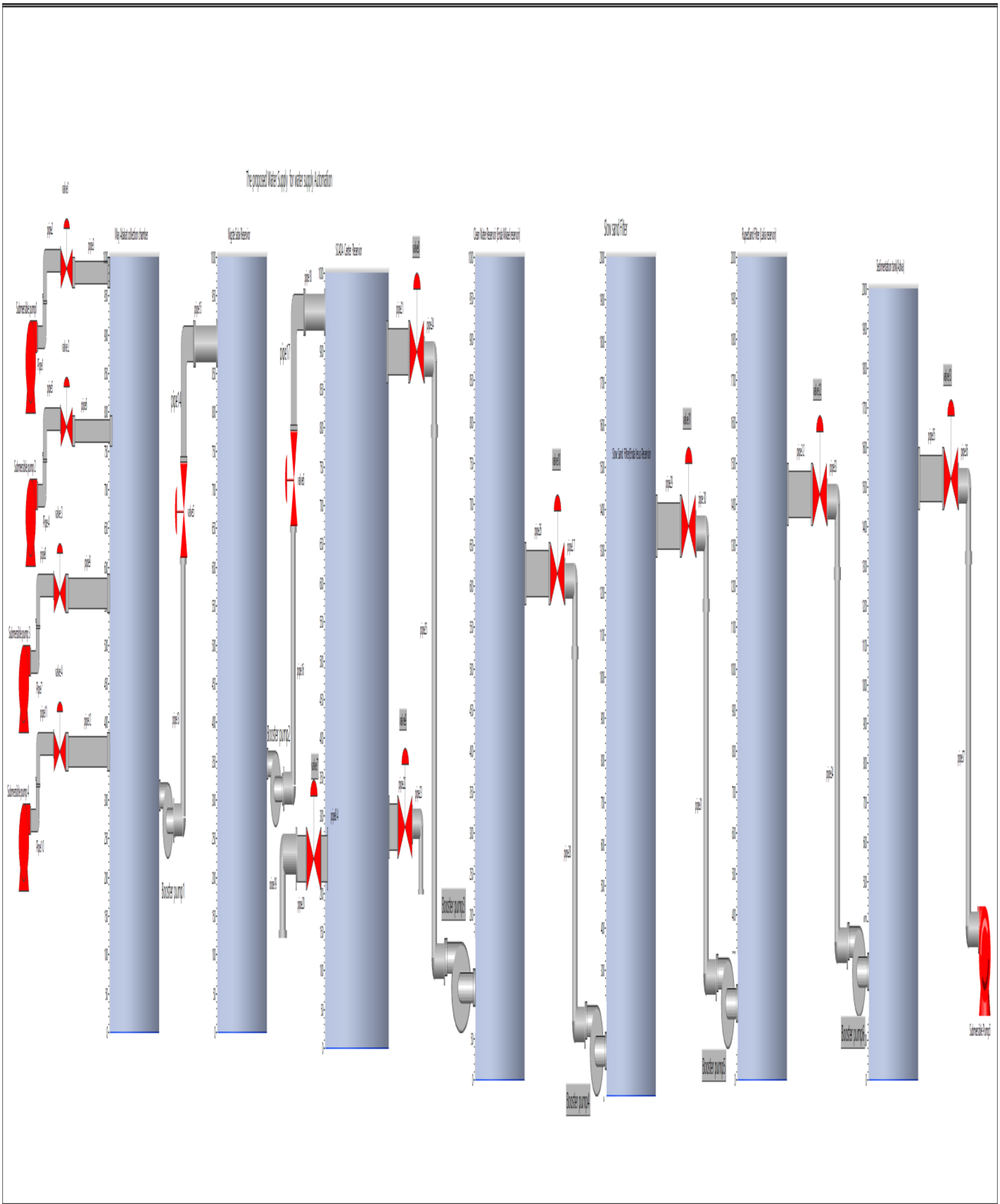

Figure 4.3 General proposed block diagram of SCADA system for water supply automation.

Operation of the system

The first phase water was pumped by Submersible pumps (SP1, SP2, SP3, and SP4) from wells stations and passed through the Valves (V1, V2, V3, V4) and pipes in to the May-abakat collection chamber, for the purpose of storing and filtering. After that it was pumped by Booster pump1 (BP1) and controlled by valve5 and collected in the Nigste Saba Reservoir and also pumped by BP2 in to the SCADA system center (main tank).

Second phase water which was pumped from Dam (Midmar Dam) by SP5 and controlled by V7 and collected into Sedimentation Tank (ST) Adwa reservoir and also pumped into RSF Lakia reservoir by the BP3 and controlled by V8 and this water also moved through the SSF Enda Selassie reservoir and pumped by pumper BP4 and managed by V9 and also collected in to CWR Enda Mikael reservoir and pumped by pumper BP5 and controlled by V10. Finally, the water was collected in the SCADA system center (main tank) pumped by pumper of BP6 and managed by V11.

4.2. System Component Description

Axum water well stations vary between new and old stations. All stations have almost the same components and instruments. Old stations component need maintenance and replacement, while new stations component are good.

For water supply system design, the main components used are divided into five main parts as follow:

Level sensor(s) – the liquid level sensors used for the design of the system played a major role in the detection, measuring, and monitoring of the water levels. Conductive sensors are used for point-level sensing. Simply put, two metallic probes of different lengths (one long, one short) insert into tank. The choice of this technique of monitoring liquid level for the automated water supply system filling system was affected by many physical and application factors. These factors include temperature, pressure, vibration, density (specific gravity) of the water, and environmental conditions particular to the automated water supply filling system.

Solenoid valve – it is a mechanical device but operated electrically. An electric current controls the valve via a solenoid. Control elements such as solenoid valves are used frequently in fluid controls. For the automatic water tank filling system using PLC, the task of the solenoid valve is to shut off or open against the flow of water into the various tanks. Solenoids are capable of switching faster and safely, it is durable and reliable. It also has low power consumption, fast and safe switching and compatible with the material used. Solenoid valves are chosen depending on the valve positions and fluid ports.

Water Pump: There are two types of pumps vertical turbine (overhead) pumps and submersible pumps. Vertical turbine pumps have high capacity as it pumps for 100-200 m^3per hour, where submersible pumps used for 40-60 m^3 per hour. Vertical turbine pumps need lubrication unit.

Lubrication Unit Used only with vertical turbine pumps to prevent friction. This unit consists of water tank (500 L) used to splash water before the pump operation.

Submersible Pump or Booster Pump –The operating pressure can be overcome by the pump developing immense pressure to achieve the desired flow rate but that will be the contribution of the pump. The flow rate of the system is dependent on the operating pressure of the system. This is affected by the system arrangements with regards to length of pipe, pipe size and fittings, height of liquid in tank and also the pressure on surface of water or liquid. The operating pressure of the system was calculated to select the desired pump for the system. This was to ensure that the required flow through the system is attained.

Reservoir: is water tank or container that has the capacity to store water. The need for a storage tank or reservoir has a long history and provides storage for water and for firefighting, chemical processing, food processing as well as many other applications. Material types such as: plastics (polyethylene, polypropylene), fiber glass, concrete, stone, stainless steel, are used for manufacturing water tanks. A water tank, container or reservoir is carefully designed such that it does not have any negative effect on the water.

Water Supply system: are needed to convey the water drawn from the source, through treatment and storage facilities, to the points where it is delivered to the supply center. The operation and maintenance of the water supply system includes upkeep of the pipes, storage tanks and pumps that convey water from the water treatment location to the main tank or main reservoirs.

The water supply system in this project consists of 1 dam site, 4 major water well plants, 6 booster pump stations, 5 submersible pump station, 6 storage tanks and 11 valves. Every node is placed 1 PLC for this SCADA project. This thesis project covers 34 PLC panels. The measurements and commands to be realized each PLC station type (dam treatment station PLC/RTU, Submersible pump, booster pump station, tank station and valve station) are as follows:

- **Dam Site Station**: PLC panels have been installed for the dam treatment stations.

They execute the following measurements and controls:

  - pH measurement at water inlet and the city outlet line,
  - Turbidity measurement at water inlet and the city outlet line,
  - Chlorine measurement at the city outlet line,
  - Dissolved oxygen measurement at the city outlet line,
  - Flow measurement at the city outlet line (instant and total flow).

The following measurements and controls are same for all the stations.

  - PLC mains power fail status,
  - PLC enclosure switch status,
  - Station main entrance door status,
  - Alarm lamp control,
  - PLC/Local selector position, etc.

- **Reservoir (Tank Station):** PLC panels have been installed for the tank stations

  They execute the following measurements and controls:

  - Level measurement at the reservoir.

The following measurements and controls are same for all the stations.

  - PLC mains power fail status,

- ❖ PLC enclosure switch status,
- ❖ Station main entrance door status,
- ❖ Alarm lamp control,
- ❖ PLC/Local selector position, etc.

❖ **Gate Valve (**Valve Station): PLC panels have been installed for the valve stations. They execute the following measurements and controls:

- ❖ Open/close valve command,
- ❖ Valve "fully open/close" switch status,
- ❖ Actuator alarm contact status,
- ❖ Valve position feedback signal measurement,
- ❖ Pressure measurement,

The following measurements and controls are same for all the stations.

- ❖ PLC mains power fail status,
- ❖ PLC enclosure switch status,
- ❖ Station main entrance door status,
- ❖ Alarm lamp control,
- ❖ PLC /Local selector position, etc.

❖ **Submersible /Booster pump (Submersible /Booster Pump Station):** PLC panels have been installed for the pump stations.

They execute the following measurements and controls:

- ❖ R/S/T phase voltage-current measurements for each pump,
- ❖ Motor body temperature measurement for each pump,
- ❖ Motor thermal shutdown status for each pump,

- Pump start/stop control for each pump,
- Pump start/stop button status for each pump,
- Pump running/stopped information for each pump,
- Inlet/outlet pressure measurements,
- Flow measurement at the city outlet line (instant and total flow).
- Flow sensor alarm status.

4.2.1. System Requirement Analysis

In order to implement the proposed system the required components are listed in the following table 4.1

Table 4.1 Components which are required for design of the proposed

List no.	Components	Activity required	Sensor/Flow rates	Field site	Alarm Status	Remark
1.	Well water1	Generating water	Level sensor	PLC	Low/High	
2.	Well water2	Generating water	Level sensor	PLC	Low/High	
3.	Well water3	Generating water	Level	PLC	Low/High	
4.	Well water4	Generating water	Level sensor	PLC	Low/High	
5.	Dam water	Water reserve	Level sensor	PLC	Low/High	
6.	Submersible pump#1	Pumping out water from well	Level sensor	PLC	ON/OFF	

7.	Submersible pump#2	Pumping out water from well	Level sensor	PLC	ON/OFF	
8.	Submersible pump#3	Pumping out water from well	Level sensor	PLC	ON/OFF	
9.	Submersible pump#4	Pumping out water from well	Level sensor	PLC	ON/OFF	
10.	Submersible pump#5	Pumping out water from well	Level sensor	PLC	ON/OFF	
11.	Booster pump#1	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
12.	Booster pump#2	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
13.	Booster pump#3	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
14.	Booster pump#4	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
15	Booster pump#5	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
16.	Booster pump#6	Pumping water from reservoir to next reservoir	Flow Sensor	PLC	ON/OFF	
17.	Valve#1	To Open/closed water	-------	PLC	Open/closed	

18.	Valve#2	To Open/closed water flow	--------	PLC	Open/closed	
19.	Valve#3	To Open/closed water flow	--------	PLC	Open/closed	
20.	Valve#4	To Open/closed water flow	--------	PLC	Open/closed	
21.	Valve#5	To Open/closed water flow	--------	PLC	Open/closed	
22.	Valve#6	To Open/closed water flow	--------	PLC	Open/closed	
23.	Valve#7	To Open/closed water flow	--------	PLC	Open/closed	
24.	Valve#8	To Open/closed water flow	--------	PLC	Open/closed	
25.	Valve#9	To Open/closed water flow	--------	PLC	Open/closed	
26.	Valve#10	To Open/closed water flow	--------	PLC	Open/closed	
27.	Valve#11	To Open/closed water flow	----------	PLC	Open/closed	
28.	Pipe#1	To carry water	Pressure sensor	-----	---	
29.	Pipe#2	To carry water	Pressure sensor	-----	---	
30.	Pipe#3	To carry water	Pressure sensor	-----	---	

31.	Pipe#4	To carry water	Pressure sensor	-----	---	
32.	Pipe#5	To Guide water flow	Pressure sensor	-----	---	
33.	Pipe#6	To Guide water flow	Pressure sensor	-----	---	
34.	Pipe#7	To Guide water flow	Pressure sensor	-----	---	
35.	Pipe#8	To Guide water flow	Pressure sensor	-----	---	
36.	Pipe#9	To Guide water flow	Pressure sensor	-----	---	
37.	Pipe#10	To Guide water flow	Pressure sensor	-----	---	
38.	Pipe#11	To Guide water flow	Pressure sensor	-----	---	
39.	Reservior#1	Water storage	Water level sensor	PLC	High/Low	
40.	Reservior#2	Water storage	Water level sensor	PLC	High/Low	
41.	Reservior#3	Water storage	Water level sensor	PLC	High/Low	
42.	Reservior#4	Water storage	Water level sensor	PLC	High/Low	
43.	Reservior#5	Water storage	Water level sensor	PLC	High/Low	

44.	Reservior#6	Water storage	Water level	PLC	High/Low	
45.	Reservior#7	Water storage	Water level sensor	PLC	High/Low	

4.2.2. Hardware Architecture of SCADA System

When designing the SCADA control system the following hard wares and soft wares are needed: Well stations and Dam are the remote sites that should be connected to the main control room which is proposed to be at Axum Municipality. The main reason of selecting this location is the fact that it is located in the middle of the city and characterized by a high altitude. This feature is preferable for possible wireless communications. Well stations and Dam contains field instruments and equipment's connected to devices being controlled and monitored. They convert physical parameters to electrical signals, which are the lower layer of the automation system. Then these devices are connected to process controllers, PLCs. Process controllers control the field devices, operate the station automatically, gathering data from the field devices and provide data to the main control room. Main control room contains SCADA servers that store data from PLCs, regulate the control system, provide HMI for the operators and send SMS messages (Alarms) to the operator. The connection between the process controllers and the SCADA servers may be established using different techniques. Figure (4.4) illustrate most common communication scenarios, nearby well stations and Dam station may be connected using direct cables (RS232, RS485 or Ethernet) while faraway stations may be connected through the radio wave (wireless private connection).

The following steps have been considered while designing the SCADA control system:

1. Definition of various components of the SCADA.
2. Identifying controlled variable and equipment.
3. Introduce the set point and priorities useful for control action.
4. Controlling equipment based on the set point and measured value.

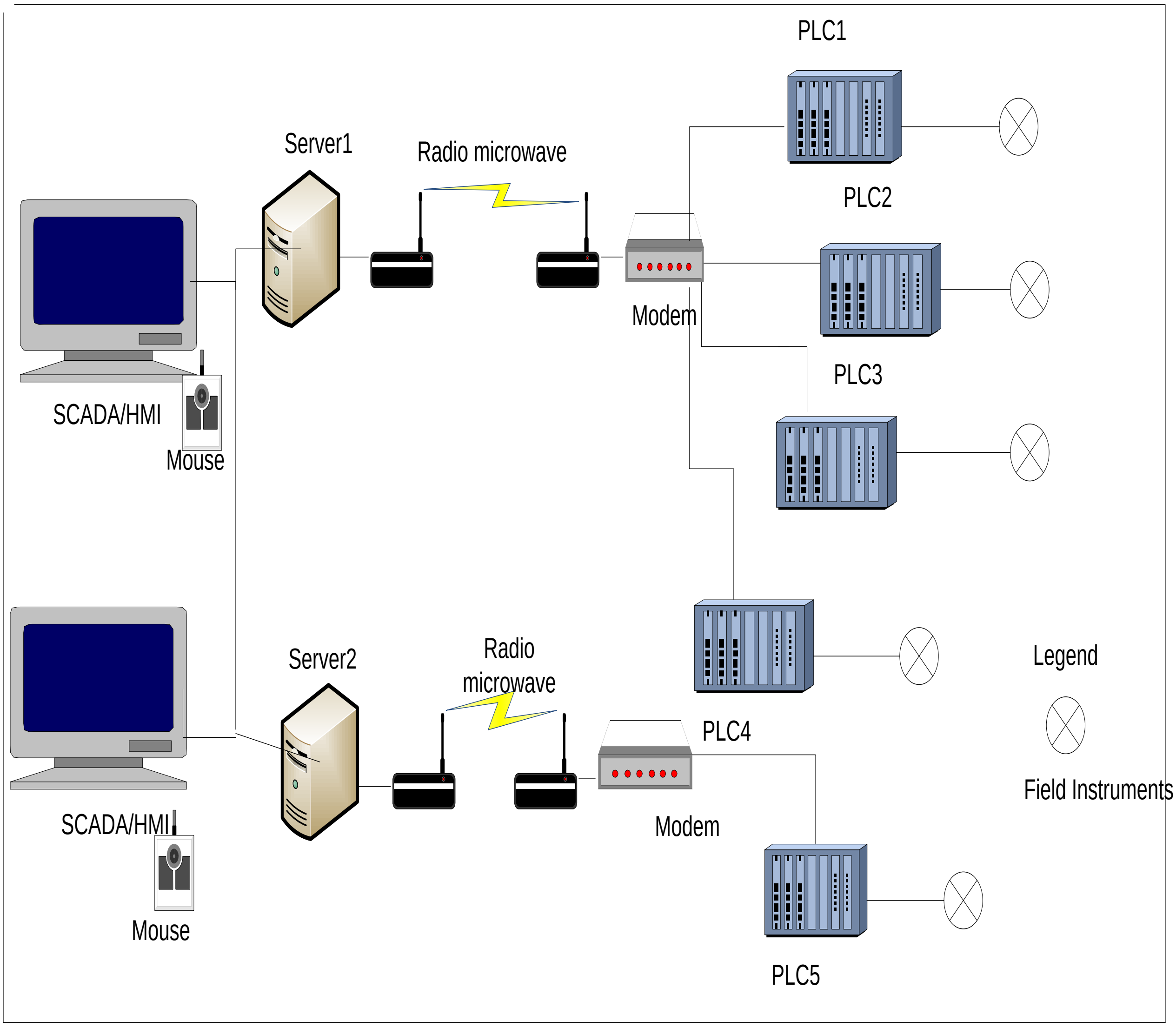

Figure 4.4 Proposed architecture of the SCADA system for water supply automation

In general, SCADA system consists of host in control station, communication network, and remote terminal unit in hardware as well as data base, control software, and application programs for software. A SCADA system usually consists of the following subsystems:

Remote terminal units (RTUs) RTU, is an IED that can be installed in a remote location, and acts as a termination point for field contacts. Dedicated pair of copper conductors is used to sense every contact and transducer value. These conductors originate at the power system device, are installed in trenches or overhead cable trays, and are then terminated on panels within the RTU.

RTU converts sensor signals to digital data. They have telemetry hardware capable of sending digital data to the supervisory system, as well as receiving digital commands from the supervisory system. RTUs often have embedded control capabilities such as ladder logic in order to accomplish Boolean logic operations. RTUs are equipped with input channels for sensing or metering, output channels for control. The RTU can transfer collected data to master terminal unit and receive data and control commands from other devices through a serial port.

RTU serves as the eyes, ears, and hands of a SCADA system. The RTU acquires all the field data from different field devices, as the human eyes and ears monitor the surroundings, process the data and transmit the relevant data to the master station. At the same time, it distributes the control signals received from the master station to the field devices, as the human hand executes instructions from the brain. Today Intelligent Electronic Devices (IEDs) are replacing RTUs.

A programmable logic controller, PLC, is used in place of RTU as field devices because they are more economical, versatile, flexible, and configurable but PLC needs an extra telemetry hard ware. Here, for this research PLC was used for system design because PLC was already installed on the existing network (the concern of this thesis).

Communication system is typically used to connect RTUs with MTU or control centers, data warehouses, and the enterprise. Examples of wired telemetry media used in SCADA systems include leased telephone lines and WAN circuits and fiber. Examples of wireless telemetry media used in SCADA systems include satellite, licensed and unlicensed radio, cellular and microwave.

Human–Machine Interface (HMI) is the apparatus or device which presents processed data to a human operator, and through this, the human operator monitors and interacts with the process. And it consist a supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the RTU. The HMI is a client that requests data from a data acquisition server.

Intelligent Electronic Devices (IEDs) includes electronic meters, relays and controls on specific substation equipment. It has the capabilities to support serial communications to a SCADA sever and reports to modern RTU via communication channels. It performs all functions of protection, control, monitoring, metering and communication. Here we use the SCADA systems for Monitoring and controlling the power.

Main control center (MTU)

At this center computer system for the SCADA will be installed. This system consists of hardware and software. This includes all the hardware devices needed to implement the SCADA system that consists of:

- SCADA server computer: this server needs to have very good specification. And will be used to install all the SCADA software packages that include software programs and tools.
- Back up SCADA server, used a backup of the main server and for redundancy
- Satellite communications are needed to connect the mater and slave

Control System: A remote terminal unit should be installed to integrate the plant with the SCADA system. Therefore, a simple control system is required to allow handling the I/O signals summarized in Table (4.2)

Table 4.2 I/O system signal

NO.	Signal	Type
1.	Is Remote	Digital input
2.	Flow meter	Analog input
3.	Pressure meter	Analog input
4.	Pump in operation	Digital input
5.	Lubrication valve	Digital output
6.	Power Fall	Digital input
7.	Generator fault	Digital input
8.	Pump operation	Digital output
9.	Fuel level	Digital input

Logout system: This is the security of the system unauthorized person does not allow to use and also in order to protect any modification in the system programming code.

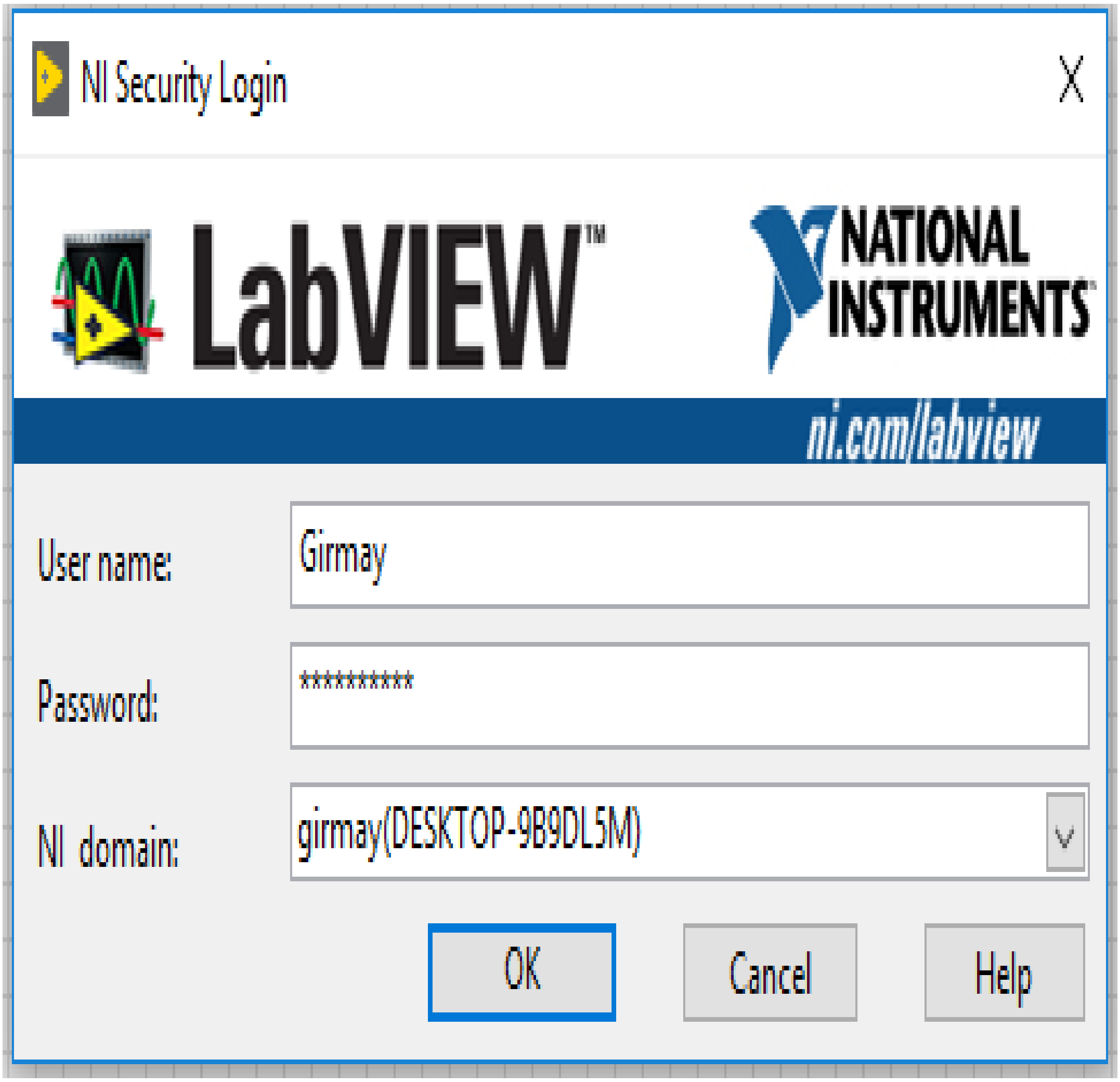

Figure 4.5 Logout system

In generally, Alarms, reports and security are main parts of the SCADA system functions. The control system generates several alarms that are used to alarm the controller if the system interred in danger state and these alarms are archived in the SCADA system. These alarms are:

1. Pump faller (Pressure)
2. Flow meter
3. Pressure meter

4. RS485 data bus are also archived in the SCADA system and used for analyzing and developing the systems
5. Generator fault.

Reports are one of the main functions and benefits of the SCADA system, recommended reports that may be generated for the system are:

1. Time of pumps operation.
2. Current of the motor pump.
3. Pressure level of the distribution line.
4. The flow rate of the water from the pump station. Security is the main control for any attach from outside of the allowed operators which are assign for control mechanisms of the system**.**

4.2.3. The Flow Chart/Algorithm

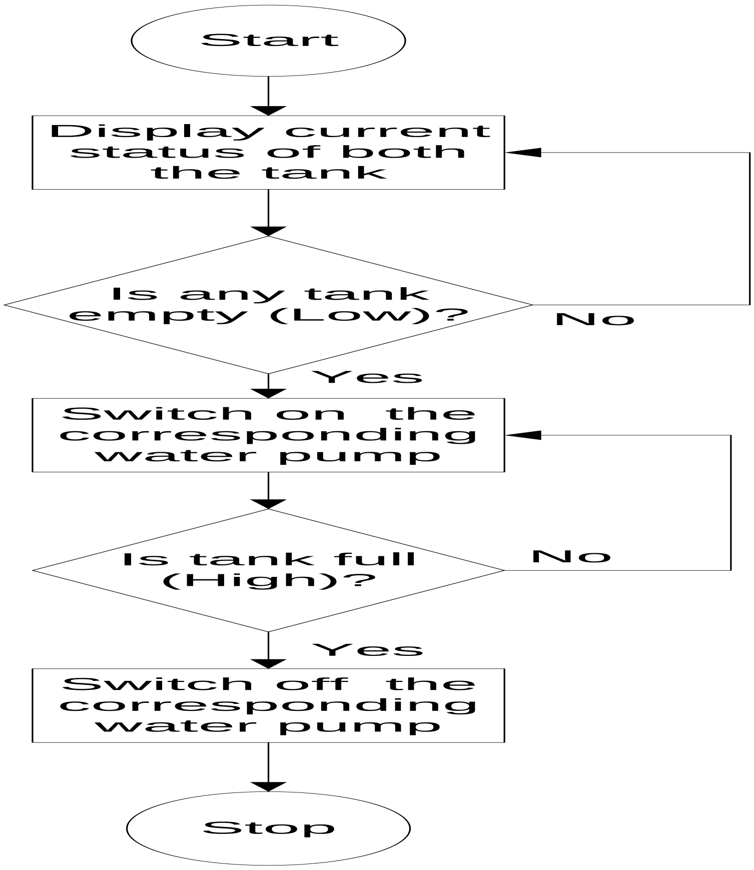

Figure 4.6 Flow chart

4.2.3.1. Software requirement

Software tools used for simulating my project is a United State of America based LabVIEW-2017 software. LabVIEW-2017 is used to draw Front panel and analyze the design and modeling of an automated LabVIEW water supply system for controlling system variables. LabVIEW include all software packages needed to implement the SCADA system.

We model the Axum water supply system using a program called graphical programming, written by LabVIEW version 2017. The name LabVIEW stands for "Laboratory virtual instrument and Engineering workbench. It is a computer aided engineering tool for the analysis of industrial, utility, and commercial water supply systems. It has been designed as an advanced integrated and interactive software package dedicated to water system and control analysis in order to achieve the main objectives.

LabVIEW works with three different classes of graphics: front panel, block diagrams, and virtual instruments. They constitute the main tools used to design new water systems, controller block diagrams and displays of results. The network model contains the numerical control inputs, numerical indicators outputs and graphical information for the water tank in which all waveform chart & wave for graph and water meter data which defines the networks and the block diagrams of the water system under study. This set of data is referred as the network data model. The proposed water supply automation of Axum Town shown in figure 5.5 and figure 5.6 is modeled using LabVIEW 2017 software. LabVIEW 2017 is the most economical solution, as data handling, modeling capabilities and overall functionality replace a set of other software systems, thereby minimizing project execution costs and training requirements. In addition, the LabVIEW have rich interfacing and system integration options (e.g. Matlab, SCADA).

4.3. Automated Control System (Automation)

Water supply system automation is the act of automatically controlling the water system via automated processes within computers and intelligent instrumentation & control devices. The processes rely on data acquisition, water system supervision, and water system control all working together in a coordinated automatic fashion. The commands are generated automatically and then transmitted in the same fashion as operator initiated commands.

Water supply system automation consists of the following main components:

- PLC/R T U
- Sensors and actuators
- H M I
- Communication equipment

Control and automation of Water supply networks play the key role in business environment for different enterprises of production, supply or distribution and metering.

4.4. SCADA in Water System Controlling

SCADA systems are globally accepted as a means of real-time monitoring and control of water supply systems, particularly for water supply, water treatment and water distribution systems. RTUs (Remote Terminal Units) are used to collect analog and status telemetry data from field devices, as well as communicate control commands to the field devices. Installed at a centralized location, such as the utility control center, are front-end data acquisition equipment, SCADA software, operator GUI (graphical user interface), engineering applications that act on the data, historian software, and other components. Recent trends in SCADA include providing increased situational awareness through improved GUIs and presentation of data and information; intelligent alarm processing; the Utilization of thin clients and web-based clients; improved integration with other engineering and business systems; and enhanced security features.

The SCADA encompasses the collecting of information via RTU (Remote Terminal Unit) relocating it back to central site carrying out decisive rehash and control and then displaying that information on a number of operating screens or displays. Based on information received from remote stations, automated or operator-driven supervisory commands can be pushed to remote station control devices, which are often referred to as field devices. Field devices control local operations such as opening and closing gate valves, collecting data from sensor systems, and monitoring the local environment for alarm conditions.

4.5. SCADA Monitoring and Control Process

As we can see from the Figure 4.7 below the monitoring part translates in to an operator in a control room, being able to “see” the remote process on the operator console, complete with all the information required displayed and updated at the appropriate time intervals. This will involve the following steps:

- Collect the data from the field.
- Convert the data into transmittable form.
- Bundle the data into packets.
- Transmit the packets of data over the communication media.
- Receive the data at the control center and decode the data.
- Display the data at the appropriate points on the display screens of the operator.

While the control process will ensure that the control command issued by the system operator gets translated into the appropriate action in the field and will involve the following steps:

- T h e operator or automatically initiates the control commands.
- Bundle the control command as a data packet.
- Transmit the packet over the communication media.
- The field device receives and decodes the control command.
- Control action is initiated in the field using the appropriate device actuation.

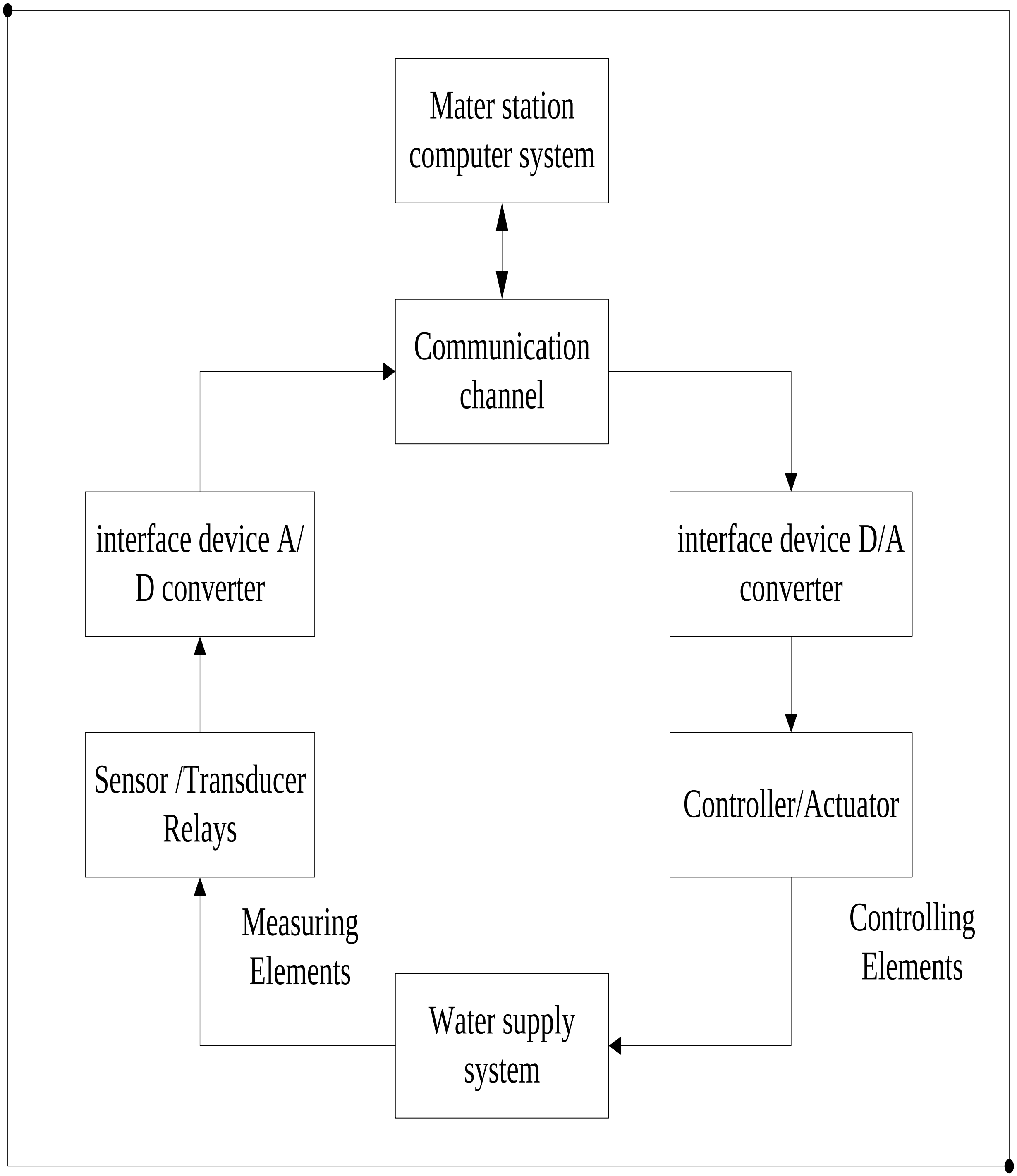

Figure 4.7 Monitoring and controlling process

CHAPTER FIVE

5. SIMULATION RESULT and DISCUSSIONS

5.1. Simulation Results and Discussion

The proposed concept of an automated SCADA control system for water supply was tested on a simulation environment implement in LabVIEW. Besides, in this section, we will explore the results of water supply automated control of main water tank (SCADA Center water tank).Then by simulation results; we verify the design of the overall system. And also, we compare of the performance system without controller and also with controller.

The performance of automatic recording system is measured as follows:

With manual recording system, report was generated once week due to this they saved 383.1m^3 water per week whereas with automated recording system, report is going to be generated on daily base which helps to save 2681.7m^3 of water per week.

Hence, the saved amount of water as result of automated recording system Vs manual is:

=Saving due to automatic reporting - Saving manual recording system

=2681.7m^3/week-383.1m^3/week

Amount of saved water =2298.6 m^3/ week

Amount of saved water (%) = (Saving automatic-Saving manual)/saving automatic

= (2681.7-383.1)/2681.3

= 85.7% performance.

5.1.1. Open Loop Control System

In the figure 5.1 shows Front Panel in LabVIEW simulation results of Open Loop control system of water supply for controlling the water tank level which was simulated for Nigste Saba Reservoir, Enda Mikael Reservoir (water tanks) and a SCADA system center (Main tank). Each tank has a capacity of 2000m^3, 2500 m^3, and 4500 m^3 respectively. In this system there was no controller mechanism. The outputs were fluctuated or varied from low to high or high to low. During the low or high level there was an alarm indicator it was shown that either it was being empty or full or also buzzer sound which was occurred when low mount of water level was existed; but, there was not a controller parameter to manage the water level of the system.

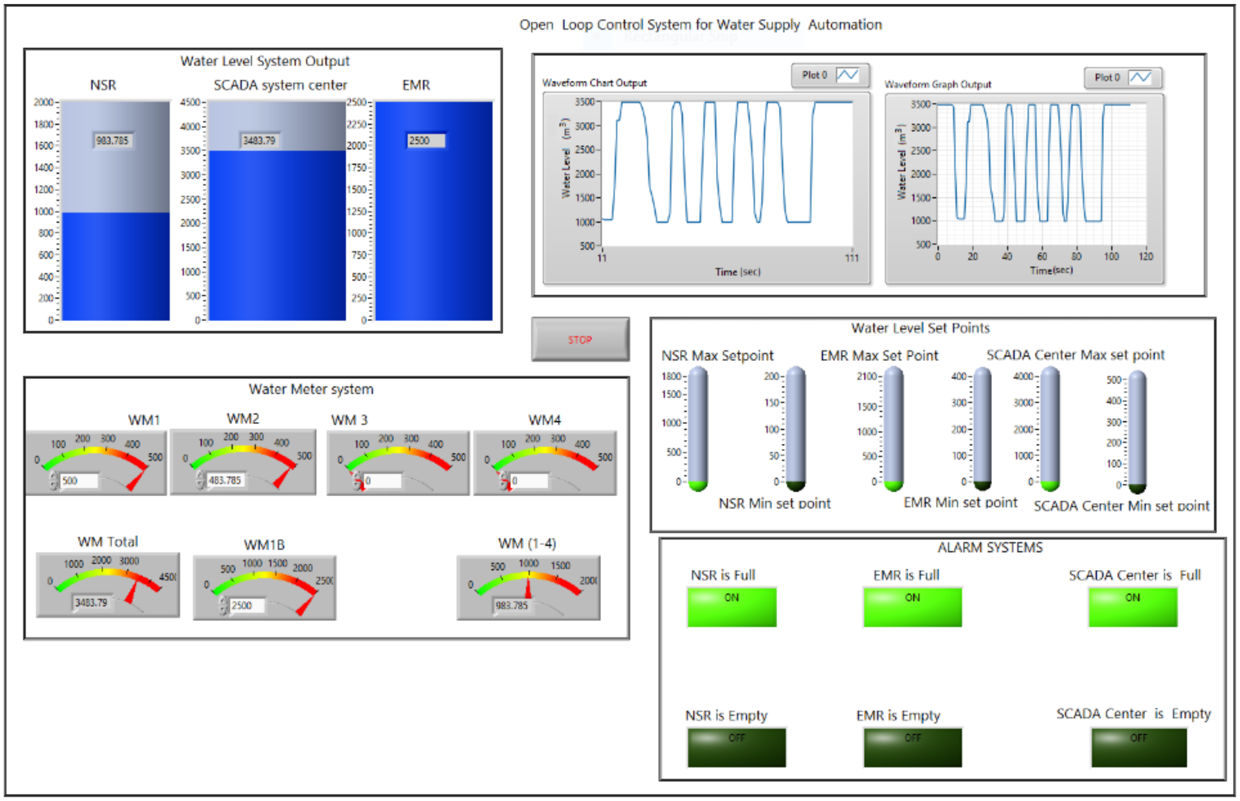

Figure 5.1 Front Panel in LabVIEW HMI Open Loop control system of water supply

In an open loop control system, the control valve only has two positions: fully close and fully open. It has possibilities either it is empty or full. As shown in figure 5.1 the alarm also showed that it was either on or off during full or empty. The outputs of an open loop control system were clearly shown in figure 5.3 and figure 5.4 in the form of waveform chart and waveform graph. Waveform chart it was used for visualized of data point by point over a short period of time. Whereas waveform graph it was used to view a certain data set over a time.

Figure 5.2 shows block diagram in LabVIEW an open loop control system of water supply for controlling the water tank level which was programmed code for Nigste Saba Reservoir, Enda Mikael Reservoir (water tanks) and a SCADA system center(Main tank).

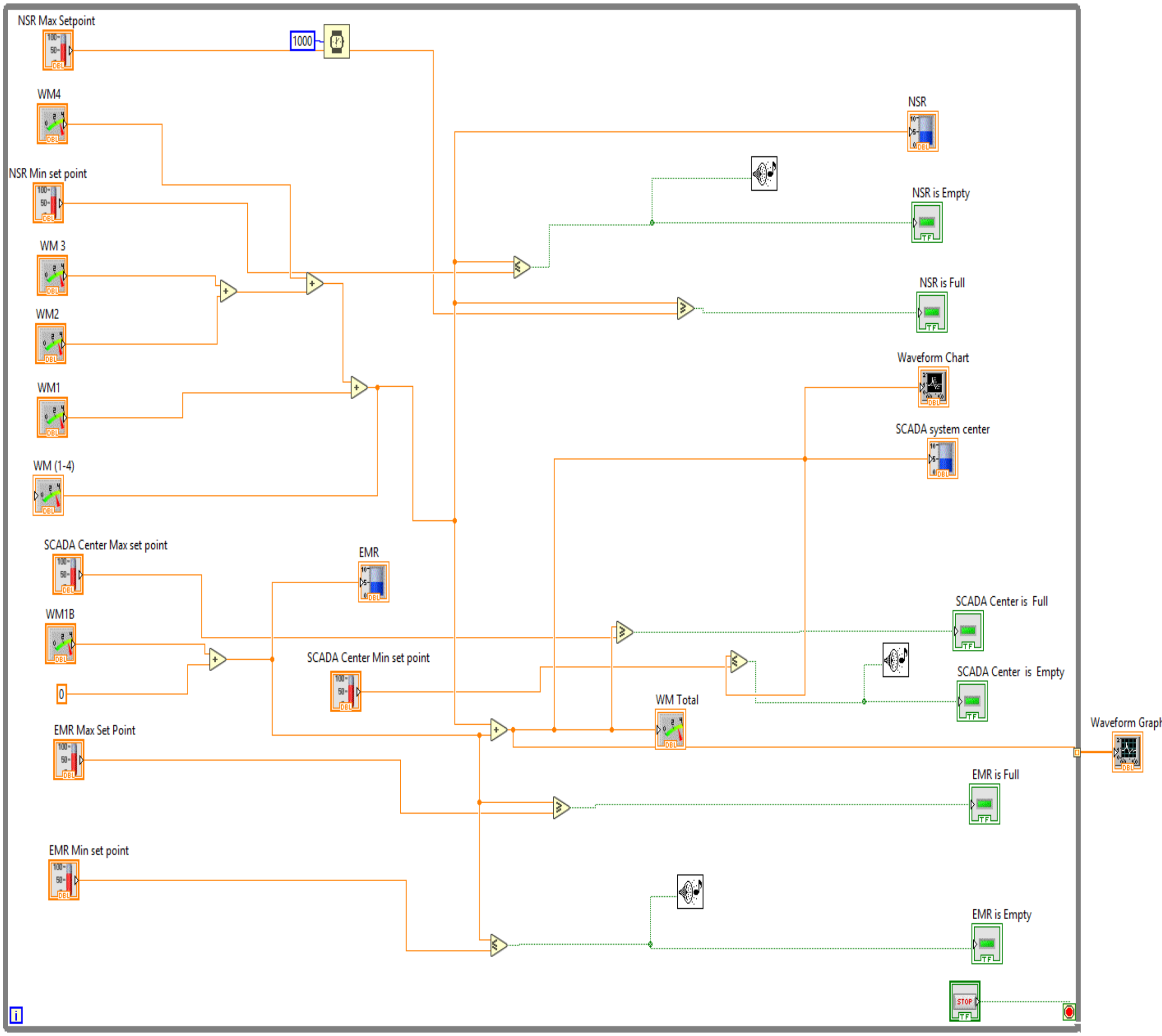

Figure 5.2 Block diagram for Open Loop control system for water supply

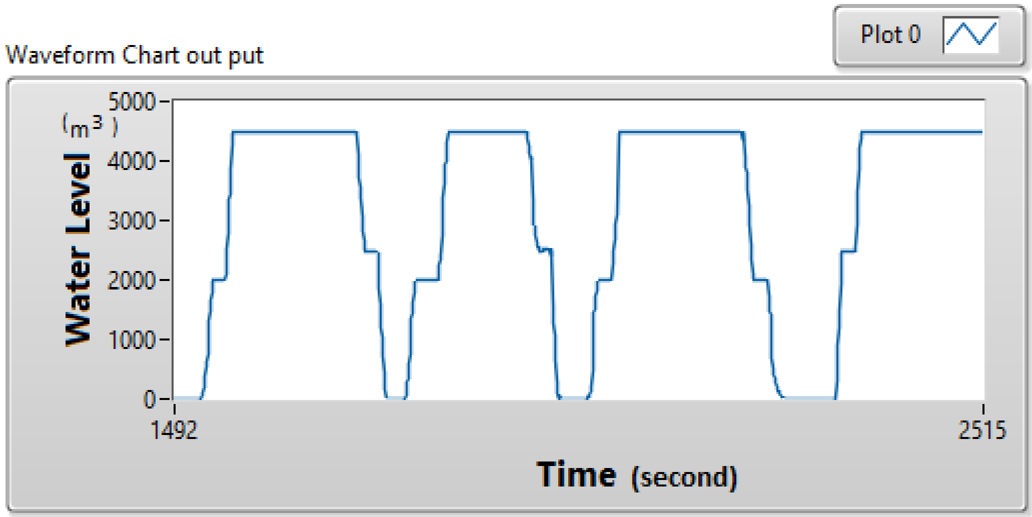

Figure 5.3 Wave form Chart Output Open Loop Control Systems for Water Supply

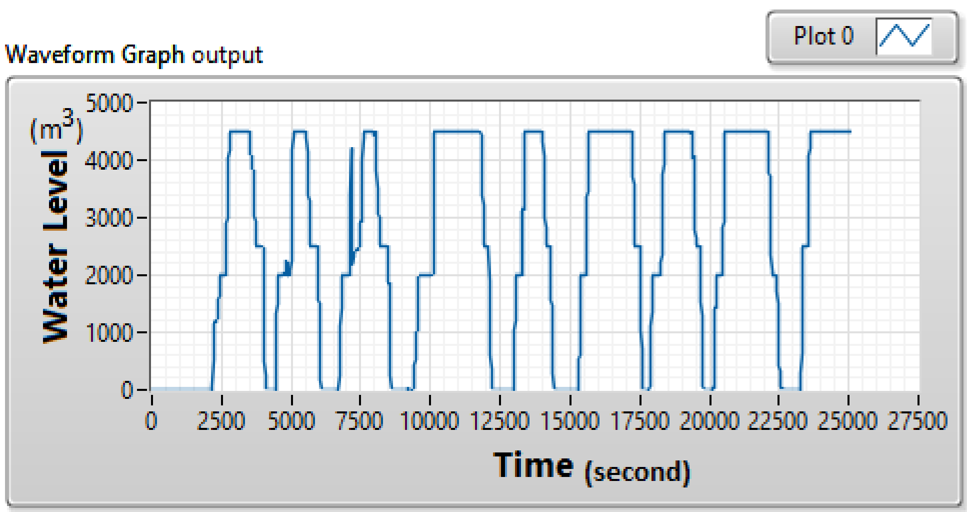

Figure 5.4 Wave form graph Output Closed Loop Control Systems for Water Supply

5.1.2. Closed Loop Control System

In the fig. 5.5 shows the complete Graphical User Interface designed in LabVIEW 2017. This is a closed loop control system of water supply which means it has a controller of the water level according to set point if there is a high amount of water enter in the reservoir the alarm should be on or if it is low the alarm will be on and it is also given buzzer sound then operator make adjust on the system. The indicators would be indicated all the conditions of the water flow in the three reservoirs. By turning the controller one can set the values as per how much a cloth has to be the desired water level. The remaining options would be set according to the set values provided by the operator. In the fig 5.7 waveform chart and fig 5.8 waveform graph were more explained the behavior of the closed loop control system and also the output is constantly stable there is not variation outputs results.

The Different from the open loop control, the position of the control valve could be adjusted upon the requirement of the system.

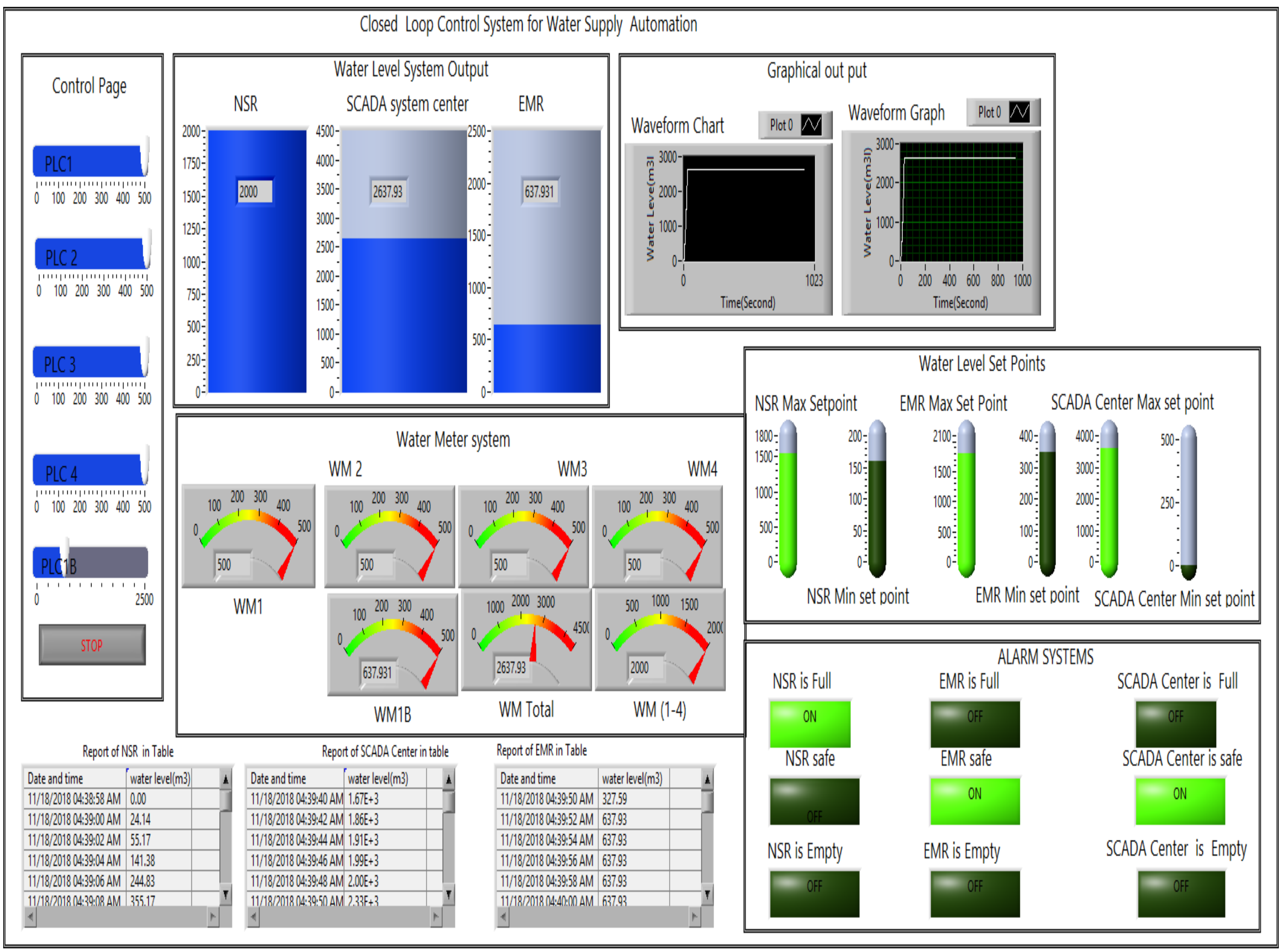

Figure 5.5 Front panel Simulation Result of HMI Closed Loop Control System

This is figure 5.6 shown that block diagram of closed loop control system graphical programming code in LabVIEW for water supply system. It is shown the overall block diagram for closed loop control system.

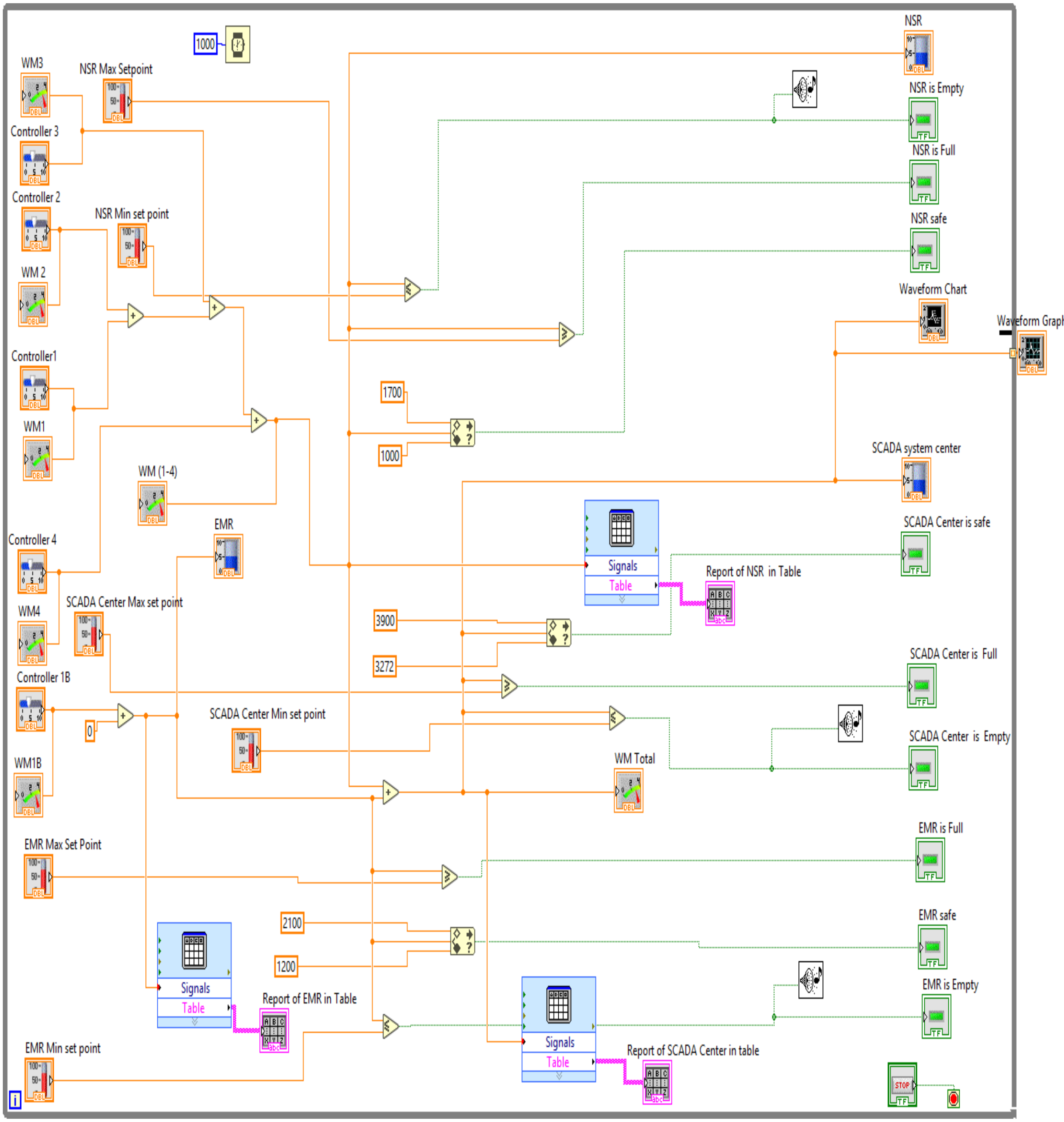

Figure 5.6 Block Diagram of Closed Loop Control System for Water Supply Automation

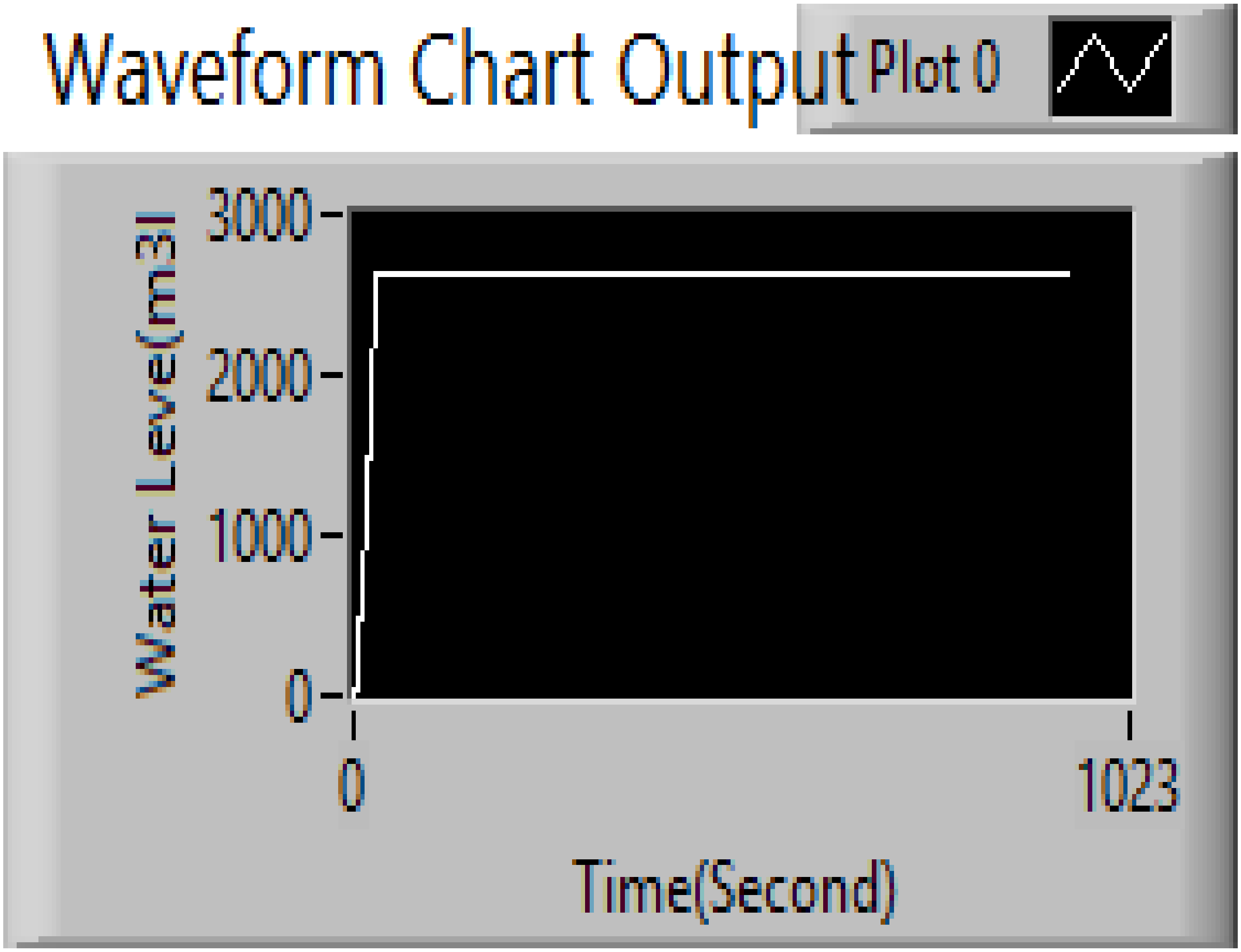

Figure 5.7 Wave form chart Output Closed Loop Control Systems for Water Supply

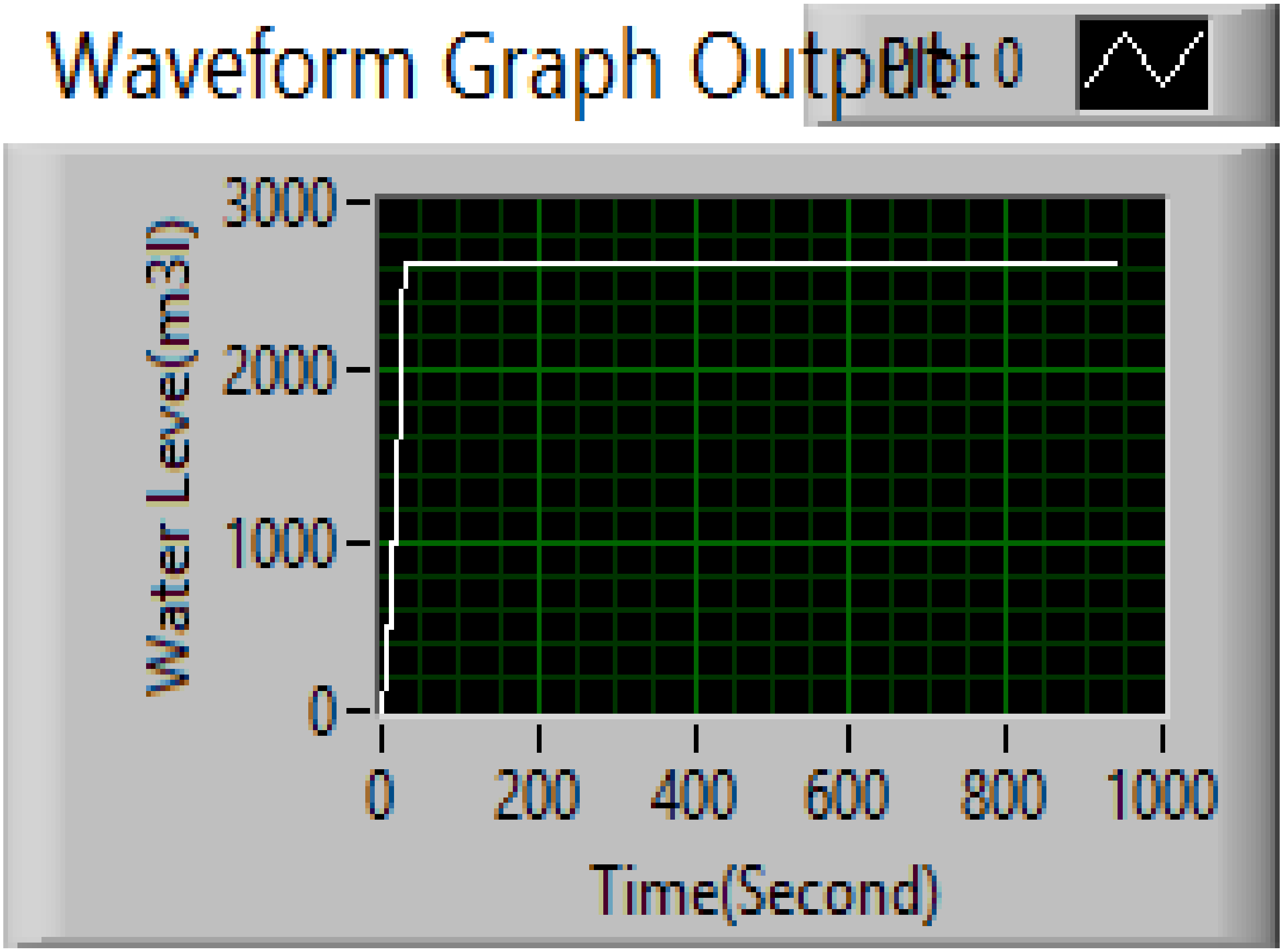

Figure 5.8 Wave form graph Output Closed Loop Control Systems for Water Supply

5.1.3. Simulation Result Discussion

The Comparison between Fig (5.1-5.4) and Fig (5.5-5.8) shows an importance of a controller. In an open loop control system Fig 5.3 waveform chart and fig5.4 wave form graph when the input from well water or dam water source increasing over a time the output of the water level either increasing or decreasing. In addition, this the output varies from low to high or from high to low. It can be seen clearly that the actual Level is not maintained at a higher level than the desired level. Also, Fig (5.3-5.4) shows that the actual level oscillates in the range of 0 to 4500 meter cubic or vice versa.

All in all, the result of open loop control system is unacceptable. However, when a controller is added, the final result in Fig (5.5-5.8) is acceptable. Because there is a time delay between the SCADA controller and the control valve, from Fig 5.7 and fig5.8, we can still see errors between the actual Level and the desired Level but the errors are invisible and acceptable.

After simulation of the water supply system in LabVIEW software, the following three results are observed:

1. Full water tank
2. Safe water tank
3. Empty water tank

1. Full water tank(High)

The Figure 5.9 Shows that TRUE value for all the level indicators denoting that liquid is presented in every level and tank is full. The Full of water level indicator of water flow in the reservoirs is shown at the same time all reservoirs are full of water. The alarm alert is automatically turned on. The range for NSR, EMR and SCADA Center reservoir is 1800, 2400 and 4000 meter cubic respectively. From this we can understand if the set point is reached the system automatically alarm is light turned on in all reservoirs.

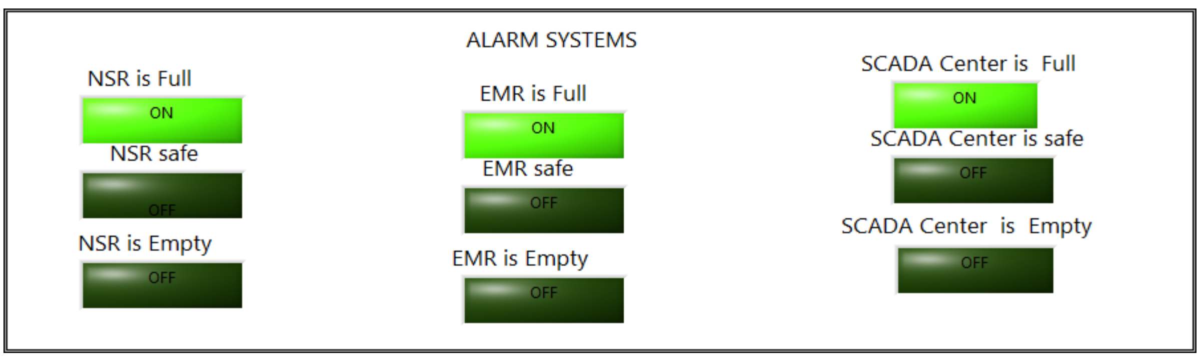

Figure 5.9 Full water tank

5. Safe tank (Medium)

The figure 5.10 is Indicated that a Safe level of water flow in the reservoirs. When the range is in the system design is (1000-1700) for NSR,(1200-2100) for EMR and (3272- 3900)for SCADA center, it is indicated that the system is operated safe mode and the light will be turned on.

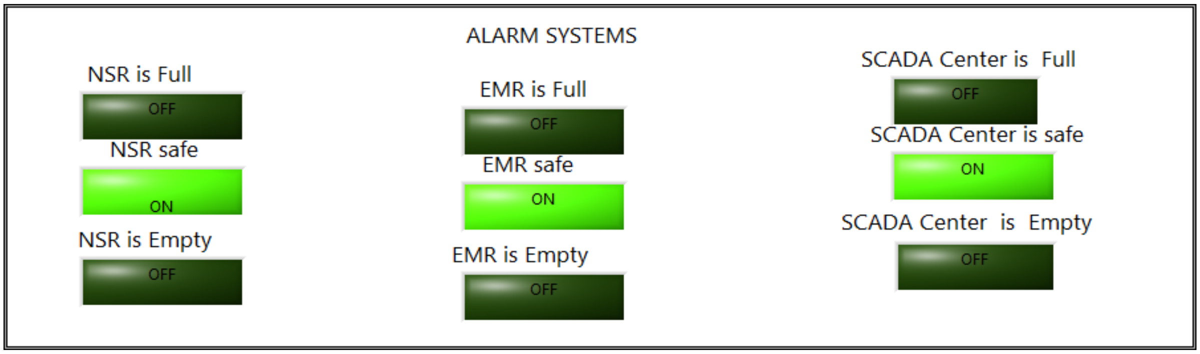

Figure 5.10 safe water tank

6. Empty tank (Low tank)

The figure 5.11 is shown an Empty of water level indicator way water flow in the reservoirs. The range for Empty tank water reservoir is 200,400 and 500 cubic meters respectively. During low level water in reservoir the alarm light is turned on besides buzzer sound is sounded in order to control the system.

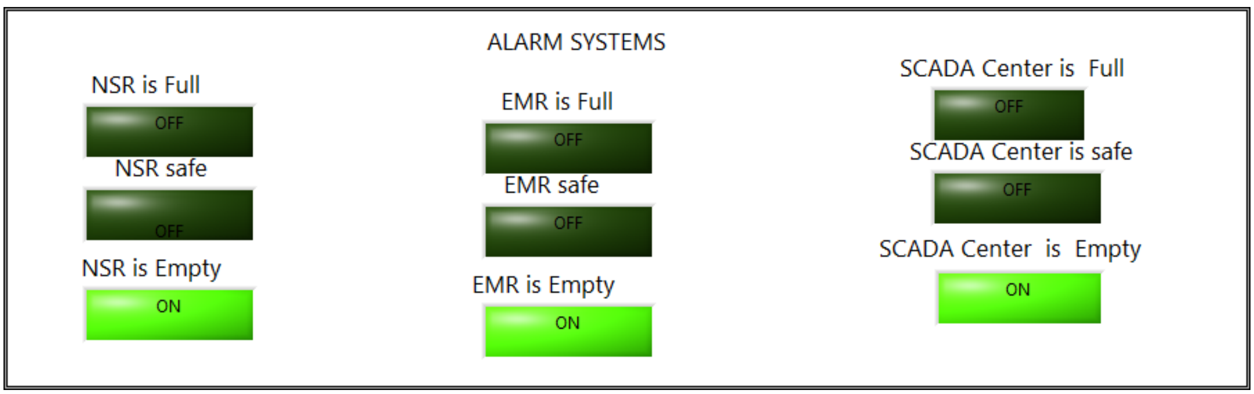

Figure 5.11 Empty water tank

From the observed three results in the water supply system safe tank (Medium) is the preferred one because it is approximated the demand of water supply of the town. In addition to this we are found the report generating in table form for each reservoirs which are listed below. These reports are included time and amount of water in each reservoir within short period of time.

Table 5.1 Indicated that the sample of Water level with in time and the amount of water supply report generating of Nigste Saba Reservoir.

Report of NSR in Table

Date and time	water level(m3)	
11/18/2018 04:38:58 AM	0.00	
11/18/2018 04:39:00 AM	24.14	
11/18/2018 04:39:02 AM	55.17	
11/18/2018 04:39:04 AM	141.38	
11/18/2018 04:39:06 AM	244.83	
11/18/2018 04:39:08 AM	355.17	

Table 5.1 Report of Nigste Saba Reservoir (NSR).

Table **5.2** Indicated that the sample of Water level with in time and the amount of water supply report generating of Enda Mikael Reservoir.

Report of EMR in Table

Date and time	water level(m3)	
11/18/2018 04:39:50 AM	327.59	
11/18/2018 04:39:52 AM	637.93	
11/18/2018 04:39:54 AM	637.93	
11/18/2018 04:39:56 AM	637.93	
11/18/2018 04:39:58 AM	637.93	
11/18/2018 04:40:00 AM	637.93	

Table 5.2 Report of Enda Mikael Reservoir (EMR)

Table 5.3 indicated that sample of water level with in time and the amount of water supply report of the SCADA water supply center of the town.

Report of SCADA Center in table

Date and time	water level(m3)
11/18/2018 04:39:40 AM	1.67E+3
11/18/2018 04:39:42 AM	1.86E+3
11/18/2018 04:39:44 AM	1.91E+3
11/18/2018 04:39:46 AM	1.99E+3
11/18/2018 04:39:48 AM	2.00E+3
11/18/2018 04:39:50 AM	2.33E+3

Table 5.3 Report of SCADA Center of Water Supply

CHAPTER SIX

6. CONCLUSION and RECOMMENDATION

6.1. Conclusion

Water is one of the most important basic needs of all living beings. It is becoming a scarcer resource partly due to huge amount of water being wasted by uncontrolled use. Existing water level monitoring systems lack functionality in terms of being able to monitor and manage multiple sources of water.

The automation of water supply system reduced water wastage. Automation system provides continuous water flow according to the set point. This project is automatic so it reduces lots of man power. The automation implemented in water supply system ensures to avoid wastage of water and reduces time.

This thesis describes an overall automation and control architecture to support the functional aspects of a water supply system facility and presents the basic knowledge needed to choose technology, design a system, and select a communication method. These descriptions are to be used in the design and implementation of a system that will support the day to day operations of the water distribution.

The supply system of a waterworks consists of pipes, valves, pumps, and appurtenances used for supplying the water; the tanks and reservoirs used for equalizing pressures and pump discharges; and the customer service pipes. A supply system should be designed so that an adequate supply of water is available to the consumers.

SCADA system is the generic term for the hardware, software, and procedures used to control and monitor these processes, and to manage the accumulated data for later study. In municipal applications, water is often pumped to long distances across extensive areas measured in square miles. To deliver optimum results, remote automation locations must be either tightly coordinated which has presented some challenges in the past with regard to real time data and event evaluation. However, advances in SCADA technology have provided alternatives to traditional approaches to manage these remote sites and helped users to speed implementations up, reduce costs, improve data integrity and resulting distribution processes, and provide significantly ease of accessibility.

There was a manual recording report which was being generated every week with inaccurate data and that misled to take wrong corrective action based on the untimely & wrong reported information. By introducing this automated SCADA system, the aforementioned problems will be reduced by 85.7% as this system will report on daily base with accurate data.

6.2. Recommendation

The quality and reliable water supply has a dominant factor in the development of the country socially and economically. Since every technology used by customers is dependable on water supply. To achieve this, it is recommended that the Axum water supply service has to consider GIS Automated SCADA System for proper operation, control and monitoring of the overall water supply system.

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APPENDIX A

A.1 Total water produces and utilized

Table A.0.1: Existing water produces and utilized data of the Axum water supply service

Years	produced water(m3)	Utilized water(m3)	Utilized (%)	wasted(m3)	Wasted (%)
2003	760544	457632	60.17	302912	32.4
2004	1007067	790957	78	216110	31.4
2005	1091820	745811	76.2	260558	23.8
2006	1126527	869562.5	77.19	256964.5	23
2007	1106953	852044.5	77	254908.1	23

Table A.0.2: Existing Reservoirs and GPS Location data of Axum water supply

Reserviors	amount m3	GPS Location			Distance from main
		X	Y	Z	
Adwa	200	487779	1568894	1914	18.62
Lakia	50	481126	1564627	2028	10.81
Endayesus	50	478567	1563612	2178	8.05
Endamikael	1000	472360	1561994	2193	
Sefho	300	469489	1559820	2149	1.86
Nigste Saba	2000	468065	1562401	2177	3.26
Mayabokat	150	466063	1560026	2075	4.98

source of water	Site	Annual capacity (M3)	GPS Location			Depth	Distance from main office
			X	Y	Z		
W-4	Mayabakat	55987.2	467283	1559504	2086	75	3.96
W-6	Mayabakat	34214.4	466990	1559505	2079	102	4.23
W-5	Mayabakat	24883.2	466139	1560030	2067	50	4.91
W-1	Mayabakat	55987.2	466027	1559851	2067	73	5.07
Arekeyti No.1		52876.8	470033	1558085	2096	150	3.01
Adwa		804816	487779	1568894	1914		18.62
Arekeyti No.2		20736	470352	1556955	2058	111	4.05
Hospital		31104	4770783	1561180	2134	111	0.11
mayshum		7464.96	470042	1562926	2164		
APW-5		31104	467846	1559660		92	3.38
APW-2		62208	463267	1559526	2044	68	7.84

Table A.0.3: Existing sources of water and GPS Location of the Wells and Dam data.