

Process Control Modelling and Simulation of a Water Plants Storage Compartments

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(Received August 20, 2020, accepted September 23, 2020)

Abstract. A water plant is one out of numerous examples of critical infrastructure which include electric power systems, traffic control systems, manufacturing systems. Humans, domestic animals, industries, and to mention a few, rely so much on these critical infrastructures as they depend solely on water plants services. However, the present situation is such that water plant falls short of its use due to breakdown, underperformance and lack of proper management in place, especially in Nigeria. This situation has hindered effective process control of water plants, thereby making it impossible to account correctly for its production process and to prevent break down of machinery. In this paper, we formulated, designed and evaluated a model that offers effective process control during production by a water plant. By means of a quantitative research approach, the study provided a full description of the flow paths and compartments connected in a process plant. We extracted information about the tanks sizes, piped diameter, number of pumps and number of tanks from the operational manual booklet of the water plants as the source of the dataset. A prototype model for the process plant was specified to establish the system's flow parts and storage compartments of mass. Based on the extracted data, we formulated mathematical models to describe the system's behaviour. The model was simulated in Simulink MatLab and used to investigate the effects of varying the parameters of the plant, especially the restriction (R) against water flow in the connecting pipes, as it affects the capacity of the tanks. The results of the simulation show that varying any of the values of the model parameters affects the water levels in the various tanks. Also, the results suggest a safe process parameter during processing. Notably, the result reveals that reducing the diameter of a pipe 1 from 300mm to 25mm or below will lead to water overflow in tanks, which will result in water wastage, machine and environmental damages. Thus, the research provided an effortless way of determining the various pipes sizes, sizes of tanks to be used and the expected output of the production process of the plant, before going into its physical production.

Keywords: process, modelling, simulation, water plant, storage.

1. Introduction

A water plant system falls under a category of systems known as critical infrastructures. Critical infrastructures include water management systems, electric power systems, traffic control systems and manufacturing systems [1]. They are known as critical infrastructures because they offer essential services to humans in today's world. Just as a lot is dependent on electricity from production and manufacturing to transportation and communication, life itself depends on water, be it humans, animals or plants. They all need water for drinking, farming, production and so on. Nevertheless, electricity depends on water for its sourcing.

The importance of water cannot be overemphasized. Hence, the need to properly manage its production and distribution is crucial. Part of managing water production is ensuring that the production process is appropriately coordinated and controlled in order to achieve proper monitoring of the production process [2].

Achieving proper monitoring of a water plant production system can be achieved through building models that describe the system behaviour, hence a model is a representation of a physical object, a system, usually, a small version of it, which is intended to increase the ability to understand, predict and possibly control the behaviour of the system under consideration [3, 4, 5].

[3] observed that the primary purpose of formulating a model is to underscore the theory beyond limiting experimental values. Specifically, it provides support for determining the optimal conditions of the flow process without really having to embark on endless tedious practical experiments.

Building models of complex system have become necessary, this is because physical systems in industry involve continuous material flows; such as: liquid, gas or solid. Because of the operational complexities, it is difficult to reach definite analytical solutions [6]. Simulation is widely used for performance evaluation of the system's behaviour [7]. It is the imitation of the operation of a real process or system with a surrogate process or model. It provides feasibility to study complex systems [6]. The models for a simulation do not only provide quantitative information, but also increases the level of understanding of how the system works.

Since water supply systems are becoming more important, water demand has also increased rapidly in developing countries as a result of high population growth, improvement of living standards, rapid urbanization, industrialization and improvement of economic conditions, while accessible sources of water keep decreasing in number and capacity [8]. It has become needful to develop a process control model for a water plant– to effectively monitor, control and predict how to handle water from the point of production. Its production output in their storage compartments is to prevent waste of water as a result of poor management, and also to ensure the safety of the machines and its environment. And, it further simulates the system to investigate, and ensure safe process parameters to adopt during production.

The rest of the paper is organized as follows: Section 2 discusses the literature review, while section 3 describes the methodology. As section 4 presents the model implementation of the study, the discussion of the result is presented in section 5. Finally, section 6 concludes the paper and identifies areas for future research.

2. Related Works

According to [2], water is an essential element required for the sustenance of life. Demand for drinking water is increasing continually with a corresponding increase in population. This ever-increasing demand can be fulfilled by designing efficient water distribution networks based on advance computing systems. These systems include modern hydraulic modelling and designing of software-based solutions. In this regard, we have presented an extensive review of softwares used in designing water distribution networks and data management of hydraulic properties of networks in this section.

A review shows that modelling softwares have been considered as tools for managing water distribution which include public domain softwares like EPANET, Branch and Loop, as well as commercial softwares, like Aquis, WaterGEMS and WaterCAD [2]. These water distribution system designing softwares differ from each other in various aspects like their functionality, compatibility to different computational systems– graphical user interfaces (GUIs), searching and optimizing algorithms, languages and programs used in their developments [2]. These qualities about these softwares make it difficult to use generally, thus the need for a more generalized platform-based approach towards modelling the management of water systems. The paper submits that the choice of water distribution network software is based on the availability of the data, time, financial implications, resources, applicability and overall purview of the project. This paper focuses on the distribution of water to targeted destinations, and not focused on monitoring the storage compartments of water plants; this is the aim of this research work.

As observed in [9], modelling is increasingly being used in water resources and river basin management, primarily because of its enormous ability to store, analyze and display numerical and spatial data [9]. Experts– as well as researchers– have applied models and software products for simulation and solutions in a variety of commercial water projects and research studies over the years. This research further presents three successive modelling examples, developed by [9]; they include: an On-Farm irrigation case on Songwe irrigation scheme (Tanzania) using model SIRMOD-III; an "Irrigation Network Operation" on Rwimi River (Uganda) using CANALMAN; and the third was applying an irrigation network module (CropMatch), developed by WMRI, in "Tanta Navigation Canal" assessment. Moreover, in such cases, modelling of irrigation networks and eco-agricultural interventions became most effective to verify functionality, guess efficiencies, validate consistency, and to avoid design mistakes and environmental hazard [9]. Generally, it was concluded that:

1. Modelling was highly recommended to verify the best economic design for agro-irrigation projects enabling adequate farm sizing, channels and drains spacing for good irrigation and drainage duties, as well as avoiding relevant problems like deficit irrigation and waterlogging.