Multi-objective optimization for Water Distribution Management System for Rathnapura District

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Abstract— Water is needed for all living things. Water distribution systems are water resources which provide water from the source to customers. Elements like valves, pipes, pumps, tanks, and reservoirs. The primary components for the urbanization are the water distribution system. Today, water distribution systems are very complex. Moreover, large investments are needed to implement and maintain them. To address these issues, it is necessary to create a system to reduce its cost and complexity. The study will concentrate on looking at the use of water distributed by the water board. The main objectives of this research are to derive an optimum water scheduling program, this research study presents a multi-objective optimization problem with the objective functions of 1. Consumed energy and 2. Pressure 3. The water level in tanks 4. Fragmentation. The optimization of both objective functions together leads to a multi-objective constrained optimization problem. To solve the problem, the Non-Dominated Sorting Genetic Algorithm, version II, (NSGA-II) is coupled to the EPANET hydraulic simulation model. In this scheme imitated the network and assess it, tank, pressure, fragment, and power, under the suggested schedule. The result of this method can be described as the most optimal level of pressure, the volume of tanks, cells, and energy levels. The future is to implement another multi-objective algorithm to compare with NSGA II.

***Keywords*—NSGA, multi-objective optimization, water distribution systems.**

I. INTRODUCTION

Water is needed for all living things. Water distribution systems are water resources that provide consumers with water from the source. Elements, such as valves, pipes, pumps, tanks and reservoirs. The water distribution system is the main parts to consider with the urbanization, and it faces sustainability and resiliency challenges including quality issues, water leaks, overuse and response to natural disasters such as floods and droughts. Today the water distribution systems are very complex. Moreover, And also those systems' need massive investment for implementations and maintenance. Considering these problems, need to create a system for minimizing their cost and complexity. This research found low cost and effective optimization of water distribution system design for smart cities using the multi-objective algorithm. Various optimization techniques have been developed to accelerate and accelerate water networks in recent years. The genetic algorithm (GAs) appears as the most popular method in their successful and varied applications. In this research used Non-Dominated Sorting Algorithm II (NSGA II).

II. RELATED WORKS

The existing old water distribution system requires additional officers and since it is pre-planned for distribution due to wastage due to waste water. SWG technology can be seen as a visual solution to address recent critical global water problems. Ensure water safety, water quality and information technology based water management solutions. For example, well-developed water and data platforms, for example, two water and data platforms are introduced. Both centralized and decentralized water distribution networks are in line with water distribution requirements of customers and supply providers. Priority is given to natural resources (e.g., rivers, tanks, groundwater etc.) for water resource and sources of production (e.g. conversion, reusable water etc.). Intelligent water gases play a key role in fulfilling the platforms and multi-resources to meet the water requirements of both consumers and suppliers. Self-diagnostic sensors and use of ICT based collaborative networks.

EPANET Free Hydraulic Network 13 software provided by the Environmental Protection Agency (EPA). An infinite number of pipe and tanks can be analysed. EPANET is a computer program that reviews long-lasting time in plumbing and water quality in the pressure pipe system. EPANET focuses to concentrate a chemical species throughout the network over a large period of timed consisting of water flow, pressure of each case, single tanks of water, and multiple periods. Adding analytic capabilities to a CAD, GIS, and database based unified networking environment can be simplified.

According to studies, there are so many gaps in the water distributed management systems. There are still economic breakdowns as a result of the lack of funding for analysis and development for barriers to adherence to good waterways, as institutional and political structures favouring the present system. The design of water distribution networks is often viewed as a single-objective, least-cost optimization problem with pipe diameters being the primary decision variables. But when we need to address several objectives, multi-objective optimization can be used to design of water distribution network instead. The single-objective approach to identifying one of the best solutions that make analysis and implementation easy. But there is a multi-objective ability to identify more than one solution. On the other hand, multiple-objective strategies (Pareto, non-dominated) solutions, resulting in one or more limited promises. So multi-objective approach is better solution method for this research.

III. METHODOLOGY EXPRIMANTEL DESIGN

Data collection

The data set used for this research is collected from the National Water Supply & Drainage Board Rathnapura.

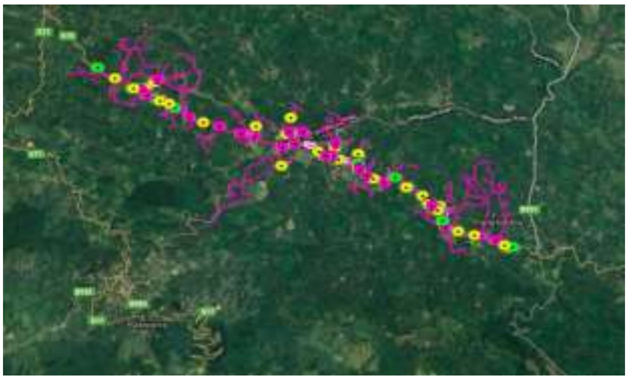

Figure 1: Water distribution system Network map on Google map

Figure 2: Water distribution system Network map on gis view

EPANET The pressure pipe system produces a long-term proportion of aquatic and quality aquifers in the aquifer. The network may include pipes, nodes (pipes), pumps, valves, and storage tanks or reservoirs. EPANET tracks the pressure at every node, the peak of water in every tank, flow of water in every pipe, and also the concentration of chemical species throughout the network throughout a simulation amount comprised of multiple time steps. Additionally, even the chemicals and chemicals can be used to limit the amount of water and supply. The EPANET Windows version provides nursing integrated processing for network compilation, regular and water quality adjustments, and a range of dashboards. These color coding network maps, knowledge tables, numerical charts, and co-ordinate landings.

A typical Water Distribution Network is as shown in Figure 1. It consists of a water reservoir, two pumps and two tanks which prevents water flowing backward.

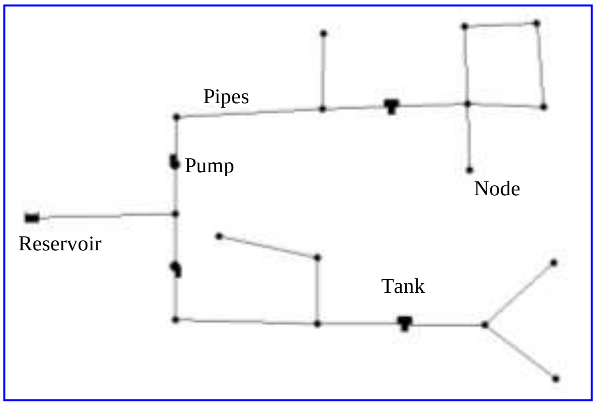

Figure 3: Example of a Water Distribution Network

Water is pumped up from the reservoir into the tanks and it's consumed at the demand node. The amount of water that can be pumped is much higher than the amount of water consumed by the water. So the pumps are not always active. Moreover, water is keep in tanks to be consumed later in a very gradual method. Water demand changes with time, and consumption patterns can be used in historical data. Therefore, pumping of pumps can be planned to minimize the cost of water supply.

Multi-objective optimization

For multi-objective improvement issues there's not one resolution, however, a group of non-dominated solutions (Pareto-set), specified the standard of an answer may be improved with reference to one criterion solely by turning into worse with reference to a minimum of one alternative criterion. Most of the systems currently used single objective optimization for water distribution systems. In this research used multi-objective optimization. Because there are more than one objectives.

- Pipes
- Pumps
- Nodes (pipe junctions)

- Reservoirs

Genetic algorithm

The genetic algorithm is a way to solve both limited and unsatisfactory optimization problems based on natural selection. The genetic algorithm changes the population in one solution each time and repeatedly. In each instance, the genetic algorithm is randomly selected from the current population and used to produce children for the next generation. Successive generations will make the population an optimum solution. In each step to create the next generation of the next generation genetic algorithms use three major laws in each step:
- **Selection rules** select people (parents) who contribute to the next generation of the population.
- Two parents are assigned to produce offspring for the right generation called **crossover rule**.
- The children make random changes to parents individually to produce children. That rule called **mutation rule**.

The genetic algorithm varies with a classical algorithm in two different ways.
- Classical algorithms generate one point in each recurrence. The order of the point is approaching a convenient solution. On the other hand, the genetic algorithm generates hundreds of millions of generators on each side. The best place for the population is to arrive at a solution.
- Classical algorithms select the next point in the sequence order. Selects the next population by calculating the random number generator using genetic algorithms.

NSGA II

NSGA stands for Non-dominated Sorting Algorithm. It relates to other Evolutionary Multiple Objective Optimization Algorithms (EMOO) (or Multiple Objective Evolutionary Algorithms MOEA). Two variants of the algorithm, the classic NSGA, and the modernized and present team are the NSGA-II forms. It is an elitist and fast multi-objective genetic algorithm and it consists of three major features.

- It emphasizes non-dominated solutions.
- It uses an explicit diversity preserving mechanism.

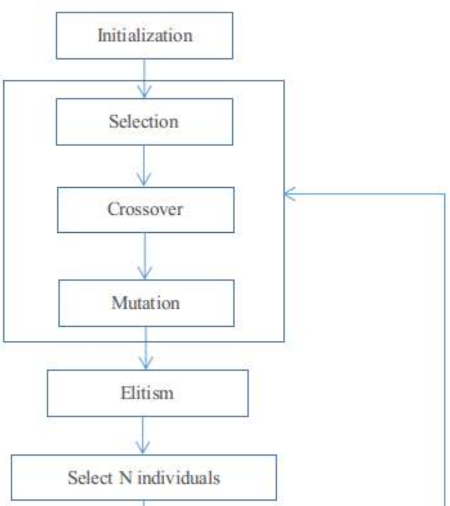

Figure 4: NSGA II structure

IV. RESULTS

This system used multi-objective optimization to design. For each step, imitate the network provided to the proposed schedule and evaluate it as follows:

- Consumed energy
- Pressure
- Water level in tanks (tanks volume)
- Fragments

Elements	**Count**
Pipes	119
Nodes	97
Pumps	2
Tanks	5
Junctions	92

Table 1: Elements count for selected network

The network provided to the proposed schedule and evaluate it as follows. The x-axis of the charts show the number of runs times. The y-axis of the charts shows consumed energy level, Pressure, the Water level in tanks, Fragments on each chart.

- Consumed energy

Overall energy consumed in the network lists in the output report of the energy section in the EPANET tools. These values get from energy section in EPANET dependencies. Figure 3 shown energy consumed chart and table 2 shown details about that chart. It shown values get from the simulation process for each run times. There are some same values also in the chart.

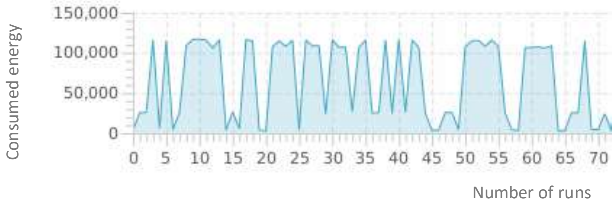

Figure 5: Consume energy chart

- Pressure

EPANET monitors the pressures on each nodes. These values also the same as the energy chart. It shown values get from the simulation process for each run times.

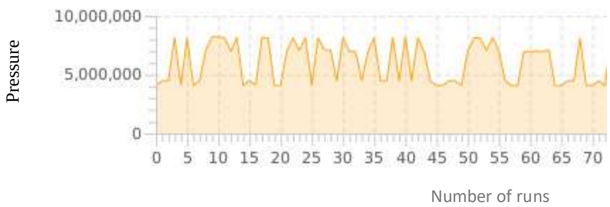

Figure 6: Pressure chart

- Water level in tanks (tanks volume)

Storage capacity with nodes is called tanks. Over time in the simulation can change the volume of stored water in the tanks. Tanks are required to operate at their maximum and minimum levels. If a tank is at its lowest, the EPANET stops flowing and stops the flow if it is at its maximum. Given chart in figure 5 shown values for tanks volume. It Variation between 100000 and 1000000 value. These values are related to the above energy values and pressure levels. In detail tank volume values are shown in the table.

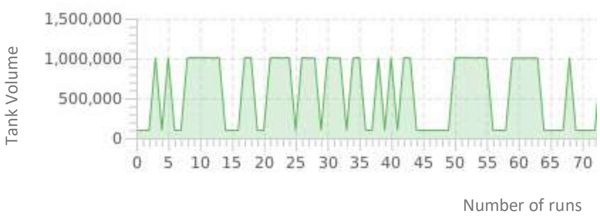

Figure 7: Tank volume chart

- Fragments

The fragment chart describes the number of species in the water distribution system.

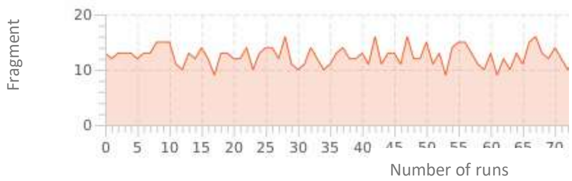

Figure 8: Fragments chart

Considering specific context within this system, the model can predict effective pressure level, tank volume, energy and fragments.

	Energy	Pressure	Volume	Fragments
1	3219.7216	4079636.752	97826.4463	13
2	116157.6625	8158037.136	1011184.82	12
3	116019.1341	8159683.258	1011184.82	9
4	5131.3088	4105735.46	97826.4463	11
5	115201.8235	8111841.195	1011184.82	14
6	108752.114	7119864.383	104522.8044	13

This method can be described as the most optimal level of pressure, the volume of tanks, cells, and energy levels.

V. DISSCUSSION AND CONCLUTION

In this research, we propose new water distribution system design and also analysis the data using new algorithm and find better method for water distributed system. EPANET Software, Data analysis tool, Multi-objective, Genetic algorithm / NSGA algorithm are the main Software / Tools requirements for this research. This system will help to evaluate consumed energy, pressure, tanks volume and fragments in water distribution system.

REFERENCES

Abido, M. a. (2006) 'Multiobjective evolutionary algorithms', *IEEE Transactions on Evolutionary Computation*, 10(3), pp. 315–329. doi: 10.1109/TEVC.2005.857073.

Abido, M. A. and Bakhashwain, J. M. (2003) 'A novel multiobjective evolutionary algorithm for optimal reactive power dispatch problem', *Proceedings of the IEEE International Conference on Electronics, Circuits, and Systems*, 3(v), pp. 1054–1057. doi: 10.1109/ICECS.2003.1301691.

Costa-Montenegro, E. *et al.* (2004) 'Distributed and centralized algorithms for large-scale IEEE 802.11b infrastructure planning', 1, pp. 484-491 Vol.1. doi: 10.1109/ISCC.2004.1358452.

Ewald, G., Kurek, W. and Brdys, M. A. (2008) 'Grid implementation of a parallel multiobjective genetic algorithm for optimized allocation of chlorination stations in drinking water distribution systems: Chojnice case study', *IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews*, 38(4), pp. 497–509. doi: 10.1109/TSMCC.2008.923864.

Horn, J., Nafpliotis, N. and Goldberg, D. E. (1899) 'A Niched Pareto Genetic Algorithm for Multiob jective Optimization', pp. 82–87.

Kulkarni, R. V. and Venayagamoorthy, G. K. (2010) 'Bio-inspired algorithms for autonomous deployment and localization of sensor nodes', *IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews*, 40(6), pp. 663–675. doi: 10.1109/TSMCC.2010.2049649.

Marques, J. *et al.* (2017) 'Water Network Design Using a Multiobjective Real Options Framework', *Journal of Optimization*. Hindawi, 2017, pp. 1–13. doi: 10.1155/2017/4373952.

Murugan, P., Kannan, S. and Baskar, S. (2009) 'Application of NSGA-II algorithm to single-objective transmission constrained generation expansion planning', *IEEE Transactions on Power Systems*, 24(4), pp. 1790–1797. doi: 10.1109/TPWRS.2009.2030428.

Di Nardo, A. *et al.* (2015) 'A genetic algorithm for demand pattern and leakage estimation in a water distribution network', *Journal of Water Supply: Research and Technology - AQUA*, 64(1), pp. 35–46. doi: 10.2166/aqua.2014.004.

Rossman, L. a. (2008) 'Epanet 2', (September), p. 104. Available at: http://www.epa.gov/nrmrl/wswrd/dw/epanet.html.

'The EPANET Programmer's Toolkit for Analysis of Water Distribution Systems Lewis A. Rossman US Environmental Protection Agency Cincinnati, Ohio 45268' (1999), pp. 1–10.

Venkata Ramana, G., Sudheer, C. V. S. S. and Rajasekhar, B. (2015) 'Network analysis of water distribution system in rural areas using EPANET', *Procedia Engineering*. Elsevier B.V., 119(1), pp. 496–505. doi: 10.1016/j.proeng.2015.08.875.

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