JalTantra: A Web-Based Free-for-All Platform for Water Network Optimal Design

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ABSTRACT

Planning and design of the water distribution system is a challenging task that involves many decision choices across many disciplines e.g. per capita investment norms, per capita water demand, minimum residual pressure, the appropriate diameter of the pipes, the suitable locations of Master Balancing Reservoir (MBR), Elevated Storage Reservoir (ESR) etc. Since per capita norm is fixed and the cost is a major constraint due to public investment, cost optimization of the entire water distribution system is a very important goal for planning and design exercise. However, comparing a large number of choices manually becomes very tedious task. Development of software to design water distribution system has emerged as an important research area and many free and commercial software have been developed. Most of the available freeware are getting obsolete and the price of the commercial software products are very high. Additionally, the commercial software products present a complex platform, which is difficult for government engineers to use.

Recognizing the need for an open-source platform to enable widespread usage in academic institutions, government offices, and other institutions, JalTantra system has been developed at IIT Bombay. The development benefited from the constant feedback of several MJP (Maharashtra Jeevan Pradhikaran) engineers. Now, it has been officially adopted as one of the software to be used in the design of water supply schemes by MJP.

JalTantra optimization framework not only covers the pipe cost but can also include energy cost of pumping water, and capital costs of pumps and storage tanks. The current system is designed for branch networks only, but it is being expanded to optimize loop type networks as well. The next version will also have Geographical Information System (GIS) based demand allocation, data management and result visualization. This paper aims to demonstrate the present capabilities of JalTantra through sample case study.

INTRODUCTION

Water supply System (WSS) is a complex system design to deliver water from source to consumer (Simukonda et al., 2018). Since WSS consists of many components of multiple type and design choices are based on per capita investment norms, per capita water demand, minimum residual pressure, the appropriate diameter of the pipes, the suitable locations of Master Balancing Reservoir (MBR), Elevated Storage Reservoir (ESR) etc. In developing countries like India, it is often planned and maintained by public health departments of state governments. Central as well state governments provide a set of guidelines to enforce a few key design choices (per capita investment norms, per capita water demand) but most of the design choices remain to be made by local engineers designing the water distribution system. Since per capita norm is often fixed and the cost is a major constraint due to public investment, cost optimization of the entire water distribution system is a very important goal for planning and design exercise. However, comparing a large number of choices manually becomes very tedious task and emergence of multiple modelling software have tried to solve this problem (Marchi, A et al.,2013). Frequently used software are either old open source freeware like Branch, LOOP or Commercial software. Most of the available freeware are getting obsolete with advancement of operating systems and the price of the commercial software products are very high. Both type of software only offers design options for WSS with limited number of pipe (Hooda & Damani, 2017). Additionally, the commercial software products present a complex platform, which is difficult for to use for majority of engineers. In this scenario recognising the need of user-friendly open source system for optimal design WSS, JalTantra System was developed at IIT Bombay with active feedback from governmental engineers.

JALTANTRA

JalTantra is an open source freeware software for optimization of water supply network. Entire water distribution can be designed in sequence or simultaneously depending on user preference. For example, user can decide to design pumping main and gravity main separately or user can opt for designing both simultaneously. JalTantra provides an easy to use interface with key result table. Methodology of design using JalTantra can be broadly classified into three categories: i) Preprocessing, ii) Optimization, iii) Post Processing.

Preprocessing steps before Optimization and Post Processing in JalTantra

1. Defining network layout with node and pipe details.
2. Assigning nodal demand.
3. Identification of source.
4. Defining details of available commercial pipe.
5. Defining key constraints like minimum nodal pressure, default pipe roughness, maximum and minimum head loss per kilometer and maximum velocity.
6. Defining soft constraint like maximum pipe pressure.

Additionally, input parameters for Elevated Storage Reservoir (ESR), Pump, and Valve must be defined if user wish to include ESR, Pump and Valve in the optimal design respectively. In large regional network ESR option can be used to size as well locate ESR optimally which is otherwise a tedious task (Hooda & Damani, 2016.) Network layout can be defined in two ways, first option is providing inputs in tabular form in Nodes and Pipes tab. Second option is defining node and pipe details in Google map interface. Figure 1 shows the detail steps for designing water supply scheme in JalTantra.

Preprocessing provides opportunity to do simulation also, if all pipe diameters are known. If designer finds existing diameter to be inadequate, he/she may choose to provide parallel pipe in addition to existing pipe. Optimization steps automatically considers above inputs while performing optimization. Optimization algorithm of JalTantra considering all feasible options (design options meeting hard constraints) and find least cost option as final design. JalTantra uses Java 7 and GLPK 4.55 Linear Program Solver. Java ILP 1.2a as the Java interface to the GLPK library (N. Hooda & Damani, 2017). The optimization in JalTantra is based on integer linear programming which provides reliable optimal solution than the heuristic optimization algorithms such as Genetic Algorithms used in some of the commercial software.

After optimization as post processing activities result can be listed with all relevant cost and technical details. Although software does not allow hard constraints to be violated if soft constraints of maximum working pressure at few pipe segments is violated, user can manually choose pipe with higher working pressure at those segments. If this constraint is violated at most of the segments, then alternative set of available commercial pipe with higher allowance for working pressure must be considered. JalTantra allows for saving both input and output files into

excel and xml formats. Additionally output can be exported into ".inp" formats which is compatible with EPANET for performing additional analysis of simulating steady state or extended period analysis.

JalTantra can be used to design following key elements of Piped Water Supply Scheme in sequence or simultaneously:

1. Gravity transmission main
2. Gravity distribution
3. Pumping main (rising main)
4. Transmission main with booster pump
5. Distribution with booster pump
6. Use of pressure reducing valve

Additional advantage of JalTantra includes identifying suitable ESR location and size in big regional network. It has option to includes practical constraint like availability of land, no ESR at non-demanding node *etc*. Since, JalTantra allows designer to segregate water supply scheme into many components and design individually, it allows for higher designer discretion. JalTantra has been evolved with active inputs from government engineers and hence follows all government norms of Piped Water Supply.

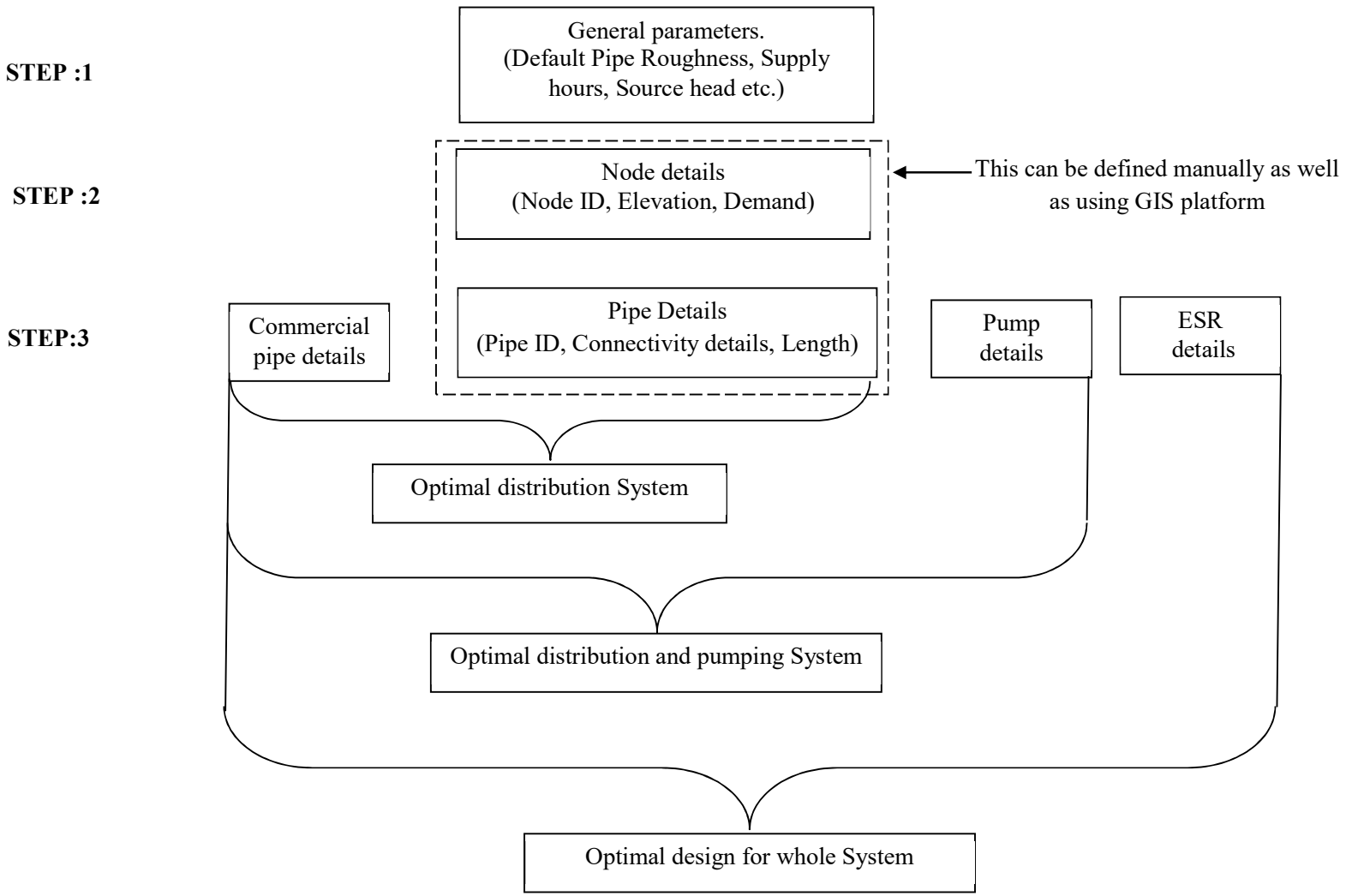

Figure 1: Design procedure of water supply system in JalTantra

CASE STUDY

Umberpada and Saphale is peri-urban area in newly formed Palghar District of Maharashtra. Due to rapid growth of this area existing water supply scheme is facing source crisis. For catering to additional demand, Gram Panchayat is considering additional supply from alternative source. This study is part of exploring feasibility of alternate option. The network consists of MBR and five ESR with three non-demanding nodes. The network layout is shown in Figure 2. The node and pipe details of the network are shown in Table 1. For this study, network layout was drawn using Google map interface of JalTantra.

Since, available commercial diameter was considered as High Density Polyethylene (HDPE) Pipes, default roughness value of 145 was considered, for old Ductile Iron (DI) Pipe roughness value of 90 was considered for designing the network. Demand was supposed to be meet in 8 hours from MBR (Node ID 1) located at 19.5901N ,72.8306E, with staging height of 19.0 m. The hydraulic gradient was maintained between 0 to 5 m/km with minimum nodal pressure of 5.0 m.

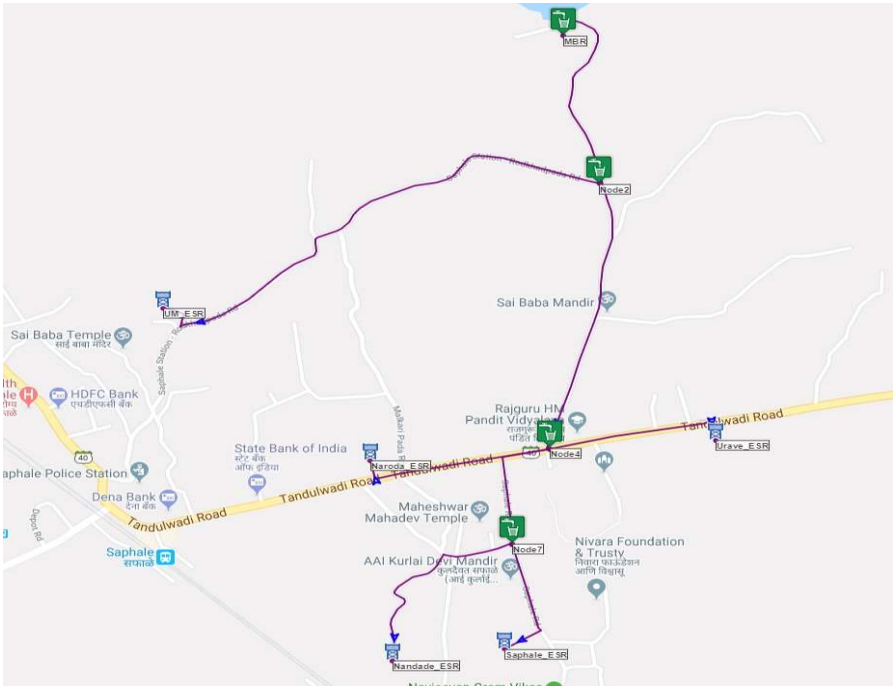

Figure 2: Transmission Network layout of the study area in JalTantra.

Table 1: Node Details of the study area

Node ID	Node name	Latitude	Longitude	Type	Demand (lps)
2	Node 2	19.5864	72.8314	Non Demand	--
3	UM_ESR	19.5833	72.8217	ESR	5.21
4	Node 4	19.5798	72.8303	Non Demand	--
5	Naroda_ESR	19.5795	72.8263	ESR	3.48
6	Urave_ESR	19.58	72.834	ESR	5.22
7	Node 7	19.5774	72.8295	Non Demand	--
8	Saphale_ESR	19.5748	72.8293	ESR	3.48
9	Nandade_ESR	19.5745	72.8268	ESR	1.74

JalTantra was used to design transmission network, where ESR and downstream network has been fixed. In option 1 we have considered design by providing only new pipe. In option 2 we have explored possibility of using some of existing pipes. Final design while considering option 1 and 2 has been summarized in Table 2.

Table 2: Optimization result from JalTantra for Design option 1 and 2

Pipe ID	Start Node	End Node	Length (m)	Design Option 1			Design Option 2		
				Diameter (mm)	Roughness 'C'	Cost(Rs.)	Diameter (mm)	Roughness 'C'	Cost(Rs.)
1	1	2	558	355	145	13,33,279	355	145	13,33,279
1	1	2	39	400	145	1,21,786	400	145	1,21,786
2	2	3	1,269	250	145	15,07,572	250	145	15,07,572
3	2	4	782	225	145	7,55,412	225	145	7,55,412
4	4	5	468	140	145	1,83,924	250	90	0
5	4	6	438	160	145	2,22,504	250	90	0
6	4	7	356	160	145	1,80,848	150	90	0
Parallel to Pipe 6			356				110	145	81,168
7	7	8	347	140	145	1,36,371	150	90	0
Parallel to Pipe 7			347				110	145	79,116
8	7	9	547	110	145	1,24,716	110	145	1,24,716
Total Cost						45,66,412			40,03,049

Parallel pipe at two segments were introduced as existing pipe diameters were found inadequate to given demand. Option 2 allow for total saving of Rs. 5,63,363 in feasibility analysis. Similar feasibility study can be conducted with pumping arrangement in place of MBR.

FUTURE DEVELOPMENT:

We aim to develop JalTantra into a standalone platform for complete Detailed Project Report (DPR) preparation. To achieve this, additional features will be developed which include:

1. Pumping machinery design.
2. Water hammer consideration in rising main design.
3. Demand allocation using GIS.
4. Node grouping and assigning zone wise demand.

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