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# A Hybrid Algorithm Based Approach for Optimization of Real Time Piped Flow Water Distribution Network to Minimize the Cost of Project Implementation

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**Abstract:** Water Distribution Systems (WDS) are one of the major infrastructure assets of the society, it is important to design economically effective water distribution system for minimizing operating cost and ease of maintenance. Designing economically effective WDSs is a complex task, which involves optimizing sizes, locations, and operational statuses of network components such as pipes, pumps, tanks and valves. The objective of this study is to minimize the implementation cost of real time water distribution network (WDN)by minimizing the diameters of the pipes. In this study first EPANET 2.0 analysis of the target WDN is carried out to determine the pipes size. The diameters of the pipe required for EPANET analysis is obtained by theoretical calculations. The system is analyzed using EPANET 2.0 hydraulic solver to determine the pressure heads at each node and velocities in each pipe. Hybrid algorithm which is combination of GA and PSO is developed and implemented in MATLAB to analyze the target WDN. The required pressure head at each junction and velocities obtained from the EPANET Hydraulic solver is given to Hybrid algorithm for the further analysis. The developed algorithm will use combination of GA and PSO optimization technic to select optimal pipe sizes by taking care of minimum required pressure heads and other operating conditions at each nodes. The resulted obtained by this analysis is compared with that of previous study which is of pure GA approach. Based on the analysis WDN is redesigned using lower level pipe sizes and hence minimizing the cost of pipes. Cost of pipe plays major role in minimizing the implementing cost of water distribution network projects and it is observed that there is a significant around 2.4% reduction in pipe cost and around 1% reduction in project cost.

**Keywords:** Water distribution network, optimization, head loss, pressure, EPANET, friction Coefficient. Genetic Algorithm, Hybrid Algorithm, PSO.

## 1. Introduction

Water is the Critical infrastructure of the society. Optimal usage of the water is the necessity of every human being. Water distribution systems play very important role in effective distribution of water from the sources to required stations. Water can be distributed through canal networks. These systems have major drawbacks like evaporation losses, major cost of implementation, land requirements, unauthorized usage of water. Piped flow systems are the remedy for drawbacks associated with canal based water distribution networks. Piped flow water distribution networks (WDN) can be gravity flow or pumped flow, branched flow or looped flow. Design and optimization of looped pipe flow water distribution network is complex compared to branched flow WDN.

Water distribution network (WDN) Fig 1.1, which is considered for previous study is considered for the present study also. It is aimed at supplying water through the pipes to fill up the natural water tanks (water bodies). It consists of 1 reservoir, 7 junctions 8 tanks and 18 pipes to carry the water to fill up the tanks. Water will flow from the reservoir 1 and flow towards junction 3. At junction 3 some volume of water will flow through pipe 9 to fill up tank 10 and remaining water will flow towards junction 4. The water will flow through all the pipes to fill up all the 8 tanks. This water distribution system carries the water by gravity flow and it has 3 loops. Mild steel (MS) pipes are used to carry water between junctions. Based on the capacity of tanks demand at each node is calculated. When the water flow in the pipes frictional and minor losses occurs and this is to be minimized.In order to maintain required flow in each pipe corresponding junctions should have minimum pressure. Pipe cost is the major part of the total implementation cost of the project which depends on pipe material, length and diameter of the pipe. In this study an effort is made to minimize the cost involved with the pipes by reducing the diameters of the pipes through Hybrid Algorithm approach. Hybrid Algorithm is developed by combination of GA and Partial Swarm optimization. In this study first EPANET 2.0 analysis of the target WDN is carried out to determine the pipes size. The system is analyzed using EPANET 2.0 hydraulic solver to determine the pressure heads at each node and velocities in each pipe. Next Hybrid algorithm is developed and implemented in MATLAB to analyze the target WDN. The required pressure head at each junction and velocities obtained from the EPANET Hydraulic solver is given to Hybrid Algorithm for the further analysis. The developed Hybrid Algorithm will select optimal pipe sizes taking care of minimum required pressure heads and other operating conditions at each nodes. The results obtained from this analysis is compared with results of our previous study which is of GA approach. Based on the analysis WDN is redesigned using lower level pipe sizes and hence minimizing the cost of pipes. After comparing the result of this analysis with previous study it is found that Hybrid approach gives optimized values and can be used for optimization of Water distribution network (WDN).

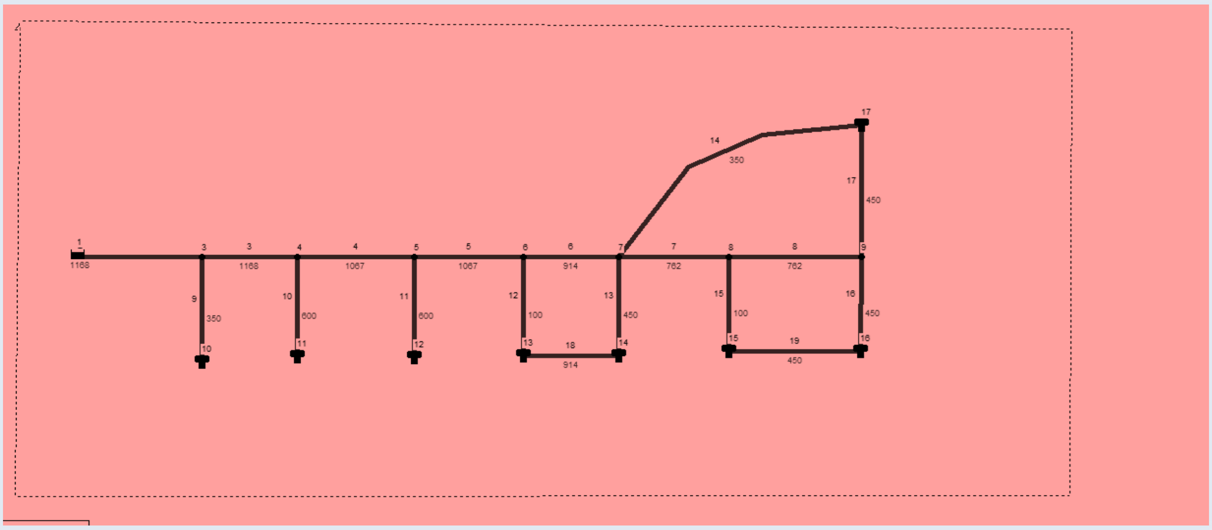


**Fig 1:** Target water distribution network (WDN)

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node and the height of water in each tank throughout the network during a simulation period comprised of multiple time steps. EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis.

Genetic Algorithms (GA) are search techniques based on the concepts of natural evolution and their principles are directly analogous to natural behavior, the brief idea of GA is to select population of initial solution points scattered randomly in the optimized space, then converge to better solutions by applying in iterative manner the following three processes (reproduction/selection, crossover and mutation) until a desired criterion for stopping is achieved.

Hybrid (GA and PSO) Algorithms are search techniques based on GA and Partial

Swarm optimization techniques. This Algorithms first generates random solutions. In First iteration GA will run to select solutions. The selected solutions will go to PSO and compared with GA to select best solutions. Similarly, many iterations carried out by selecting best solution from the previous iterations. When convergence occurs the corresponding result will be optimized one.

MATLAB (**Mat**rix **Lab**oratory), a product of Math works, is a scientific software package designed to provide integrated numeric computation and graphics visualizationin high-level programming language. MATLAB has a wide variety of functions useful to the genetic algorithm practitioner and those wishing to experiment with the genetic algorithm for the first time. Given the versatility of MATLAB's high-level language, problems can be coded in m-files in a fraction of the time that it would take to create C or Fortran programs for the same purpose. Couple this with MATLAB's advanced data analysis, visualization tools and special purpose application domain toolboxes and the user is presented with a uniform which to explore the potential of genetic algorithms.

## 2. Literature Review

Many of the researcher used GA based approach for design of water distribution network. simple genetic algorithms (GA) is used to obtain near optimal solution [1], while Simpson et al. [2] compared GA technique with other methods, and concluded that the GA technique generates multiple alternative solutions which are optimum. The results obtained by Simpson Dandy et al. [3] improved the solutions obtained by Simpson using the concept of variable power scaling of the fitness function, an adjacency mutation operator, and grey codes. Savic and Walters developed the computer model GANET [4] to obtain least cost of water distribution system. Prasad and Park considered both minimization of cost and maximization of network reliability [5] in GA, Harmony search method is used [6] by Geem for optimization of water distribution network. Multi objective approach is used [7] in optimization. G C Dandy further improved GA [8] for obtaining better solutions. Chandramouli and Malleswararao [9] used fuzzy logic based approach to improve the reliability of network. Cisty [10] used search space reduction approach to improve computational efficiency, minimization of electricity cost [11] is also considered in optimization, combining GA and mathematical programming with the inclusion of new elements such as pressure reducing valves [12]; Surco et al. utilized a modified particle swarm optimization (PSO) algorithm for the optimization of water distribution networks [13], Antonowicz used EPANET solver for solving water distribution network[14], [15], [21], Beatriz, Martinez-Bahena used GA for optimizing real time water distribution network [16],Wu and Simpson [17] demonstrated significant improvements in efficiency and robustness for single-objective optimization utilizing a boundary search method, Bilal and Pant utilized a hybrid metaheuristic algorithm[18]. Comparison of searching behaviour of evolutionary algorithms [19], Investigating the Impacts of Water Conservation on Water Quality in Distribution Networks Using an Advection-Dispersion Transport Model [20], Tanyimboh, T.T. "Redundant binary codes in genetic algorithms [22], Pant, M used novel differential techniques for optimizing WDN [23], Hybrid algorithm using PSO and Tabu search is used for optimization of large scale water distribution network [24],Sangroula, U. carried out Optimization of Water Distribution Networks Using Genetic Algorithm Based SOP–WDN [25].

## 3. Hydraulic Analysis of WDN using EPANET

Hydraulic analysis of the water distribution network is carried out using the diameters obtained by theoretical analysis keeping all other input values same. The WDN is drawn by adding reservoir, nodes, Tanks and pipes. Input values for the reservoir, pipes, nodes and tanks are added and the system is analyzed. Since the peak demand occurs initially corresponding values are recorded and tabulated. It is also important to understand the unit head loss in each pipe as the head available at next junction is the difference of between head at previous junction and head loss in corresponding pipe. Unit head loss plot for different diameters is shown in fig 3.

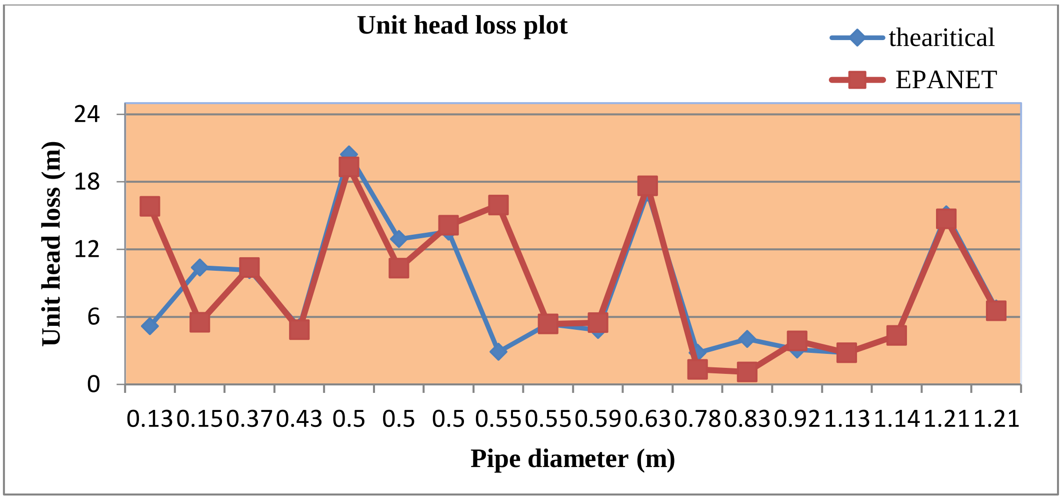


**Fig 2:** Unit head loss comparison plot

It is observed that for most of the pipes unit head loss is minimized in case of EPANET analysis as compared to theoretical analysis carried in our previous study. Fig 3.1, 3.2 and 3.3 shows the output of EPANET analysis.

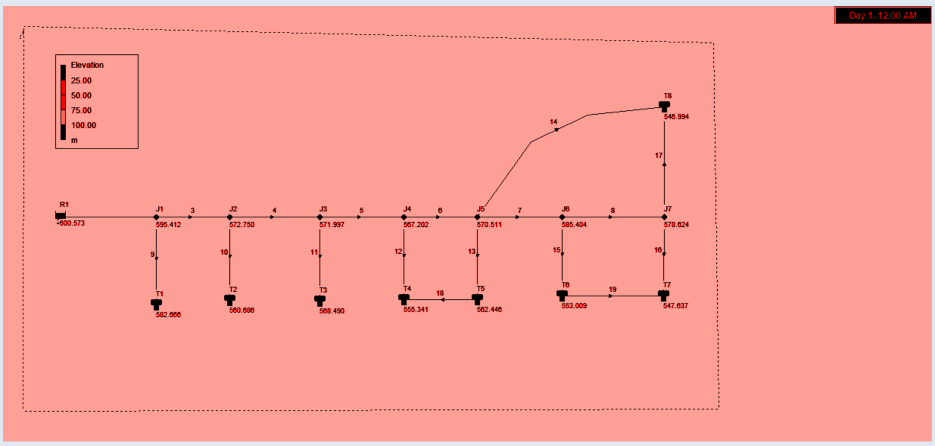

**Fig 3:** Elevations at junctions and Tanks

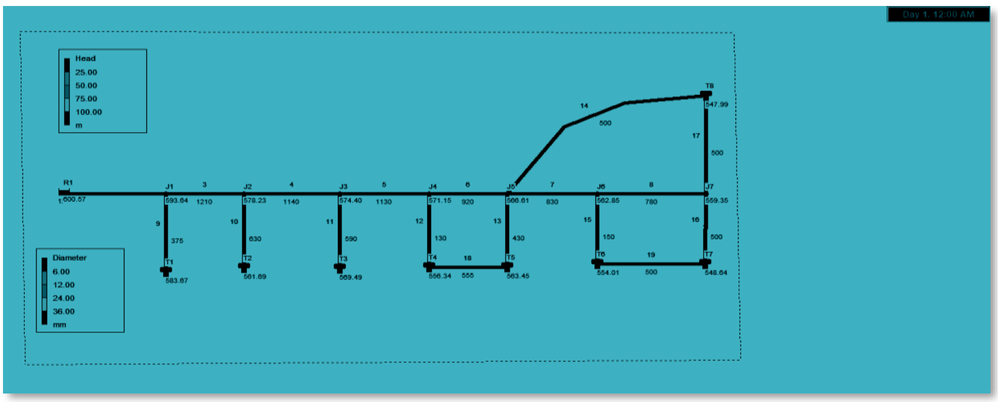

**Fig 4:** Pressure head and diameter value

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### 4. Development of Hybrid (GA and PSO) Algorithm and implemented in MATLAB2016

To carry out this study we developed Hybrid algorithm which combines the features of both the methods and is implemented in the MATLAB 2016. Developed algorithm works on the following Logic.

1. Hybrid algorithm reads the input file for necessary data for processing.
2. It is suggested to use larger diameter pipes to minimize the head loss. Larger diameter pipes increase the cost of pipe. This GA selects the optimal pipe diameters in the pipe network to minimize the pipe cost maintaining required head at each junction in the pipe network so as to allow the required discharge to fill the tanks.
3. In first iteration GA runs and develops the solutions from the populations. These solutions are compared with that of PSO solutions.
4. Next PSO algorithm will run by selecting best solutions from GA algorithm and generates PSO solutions. The PSO solutions will be compared with GA solutions to select best solutions to complete first iteration. Same process will be repeated in subsequent iterations. Algorithm will show best diameter values and cost in each iteration. When convergence happens same diameters and cost values repeats for further iterations. These solutions are considered as optimal solutions.
5. Any number of iterations can be run for the Algorithm.
6. It considers the flow between Reservoir and junction J1. Initially in first iteration it selects maximum diameter pipe out of available diameter steps. Using Hazen Williams formula calculates frictional losses. It adds 10 percent of frictional losses to calculate total losses in the flow from Reservoir to junction J1. It deducts the total head loss from the head available at reservoir. The result will be compared with head available at J1. If the resulted head is more than the junction head Hybrid algorithm selects next lower diameter values and perform the above steps. This will repeat for all the junctions.
7. Based on the selected values of pipe diameter it will calculate the total optimized cost of the pipe.

We created the input file to run the developed Hybrid Algorithm Following input files in the form of matrix is created

1. Head Required at each junctions
2. Start and End elevations
3. Conversion factor for Hazen- Williams equation
4. Theoretical diameter of pipes
5. Roughness coefficients of pipe material
6. Pipe lengths
7. Commercially available Standard Diameter of Pipe and Cost/meter

### 5. Pseudo Code of Hybrid (GA PSO) Algorithm

```
% First generate random solutions
% Then start the first part of iteration GA and compare GA results with PSO results and choose best
% These solutions go to PSO Algorithm and create new solution and compare the new solutios with GA and choose best
% And so on like Cuckoo algorithm (CA)

%------------------------------------------------------------------

clc;clear;close all
CostFunction=@(x) Cost(x);    % Cost Function
nVar=18;                      % Number of Decision Variables
VarSize=[1 nVar];             % Decision Variables Matrix Size
```

```
VarMin=1;                  % Lower Bound of Variables
VarMax= 25;                 % Upper Bound of Variables

%% Diameter of pipes
% Standard Diameter available
D=xlsread('C:\HP_Final\Input_Data\Input_Data','Standard_Dia','C3:AB3');


MaxIt=2;      % Maximum Number of Iterations
nPop=6;       % Population Size (Swarm Size)
VelMax=0.1*(VarMax-VarMin);
VelMin=-VelMax;
% PSO Parameters
w=1;           % Inertia Weight
wdamp=0.99;    % Inertia Weight Damping Ratio
c1=1.5;        % Personal Learning Coefficient
c2=2.0;        % Global Learning Coefficient
pc=0.7;               % Crossover Percentage
nc=2*round(pc*nPop/2);  % Number of Offsprings (also Parnets)
pm=0.3;                % Mutation Percentage
nm=round(pm*nPop);     % Number of Mutants
mu=0.1;        % Mutation Rate
beta=8;
empty_particle.Cost=[];
empty_particle.Velocity=[];
empty_particle.Best.Position=[];
empty_particle.Best.Cost=[];
for i=1:nPop

% Initialize Position

    m=randi([1 25],VarSize);

    pop(i).Position=m;
    pop(i).Position=D(m);

% Evaluation
   pop(i).Cost=CostFunction(pop(i).Position);

   particle(i).Position=pop(i).Position;

% Initialize Velocity
   particle(i).Velocity=zeros(VarSize);

% Evaluation
   particle(i).Cost=pop(i).Cost;

% Update Personal Best
   particle(i).Best.Position=particle(i).Position;
   particle(i).Best.Cost=particle(i).Cost;
```

```
end

Costs=[pop.Cost];
[Costs, SortOrder]=sort(Costs);
pop=pop(SortOrder);
% Store Best Solution
BestSol=pop(1);
% Array to Hold Best Cost Values
BestCost=zeros(MaxIt,1);
% Store Cost
WorstCost=pop(end).Cost;
for it=1:MaxIt
   disp('GA Start')

   P=exp(-beta*Costs/WorstCost);
   P=P/sum(P);

   popc=repmat(empty_individual,nc/2,2);
for k=1:nc/2

% Select Parents Indices
      i1=RouletteWheelSelection(P);
      i2=RouletteWheelSelection(P);
      p1=pop(i1);
      p2=pop(i2);

% Apply Crossover
     [popc(k,1).Position, popc(k,2).Position]=Crossover(p1.Position,p2.Position);


%%

% Evaluate Offsprings
      popc(k,1).Cost=CostFunction(popc(k,1).Position);
      popc(k,2).Cost=CostFunction(popc(k,2).Position);
end
   popc=popc(:);


   %%

% Mutation
   popm=repmat(empty_individual,nm,1);
for k=1:nm

% Select Parent
      i=randi([1 nPop]);
      p=pop(i);

% Apply Mutation
      popm(k).Position=Mutate(p.Position,mu,VarMin,VarMax);
```

```
 %%
% Evaluate Mutant
        popm(k).Cost=CostFunction(popm(k).Position);

end

% Create Merged Population
    pop=[pop
        popc
        popm]; %#ok

% Sort Population
    Costs=[pop.Cost];
    [Costs, SortOrder]=sort(Costs);
    pop=pop(SortOrder);

%----------------------------------------------------
% for population and cost iterationwise details
    populationPosition=vertcat(pop.Position);
    PopulationCost=vertcat(pop.Cost);
    Population_Cost=[populationPosition PopulationCost];
%----------------------------------------------------

% Update Worst Cost
    WorstCost=max(WorstCost,pop(end).Cost);

% Truncation
    pop=pop(1:nPop);
    Costs=Costs(1:nPop);

% Store Best Solution Ever Found
    BestSol=pop(1);

%end
%--------------------------------------------------------
% Store Best Cost Ever Found

for i=1:nPop
if pop(i).Cost<=particle(i).Cost
            particle(i).Position = pop(i).Position;
            particle(i).Cost = pop(i).Cost;
end
        Cx(i) = particle(i).Cost;
end
    [BestCost(it),r]=min(Cx);
    GlobalBest.Cost=particle(r).Cost;
    GlobalBest.Position=particle(r).Position;

    BstCostGA(it)=BestCost(it);
```

```
   disp(['Iteration ' num2str(it) ': Best Cost = ' num2str(BestCost(it))]); % Displaing Iteration number and
solution
%end
 disp('GA End')
 disp('PSO Start')

for i=1:nPop
%  for i=1:2
% Update Velocity
        particle(i).Velocity = w*particle(i).Velocity ...
            +c1*rand(VarSize).*(particle(i).Best.Position-particle(i).Position) ...
            +c2*rand(VarSize).*(GlobalBest.Position-particle(i).Position);

% Apply Velocity Limits
        particle(i).Velocity = max(particle(i).Velocity,VelMin);
        particle(i).Velocity = min(particle(i).Velocity,VelMax);

% Update Position
        particle(i).Position = particle(i).Position + particle(i).Velocity;

%          % Velocity Mirror Effect
        IsOutside=(particle(i).Position<VarMin | particle(i).Position>VarMax);
        particle(i).Velocity(IsOutside)=-particle(i).Velocity(IsOutside);

% Apply Position Limits
        particle(i).Position = max(particle(i).Position,VarMin);
        particle(i).Position = min(particle(i).Position,VarMax);
        xx=particle(i).Position;
%%-------------
%This finds the value in D which is closest to the particle(i) value I am calling.

parti=[];
for j=1:length(xx)
[c index] = min(abs(D-xx(j)));
%In this case Im looking for the closest value to 'V(1)' which is 2000. It should return the 3rd or 5th value of N
which is 2001.
%Note: 'index' is the index of the closest value. If two are the same, like in this example with two different
'2001's, it will return the index of the first one.
closestValue_for_N = D(index);
particle(i).Position=closestValue_for_N;
parti(j)=particle(i).Position;
end
particle(i).Position=parti;

%---------------------------------------------------
% for population and cost iterationwise details
     populationPosition=vertcat(particle(i).Position);
     PopulationCost=vertcat(particle(i).Cost);
     Population_Cost=[populationPosition PopulationCost];
%---------------------------------------------------
% %%-------------------------------------
```

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```
% Evaluation
        particle(i).Cost = CostFunction(particle(i).Position);
% value = getfield(particle,'Position')
% Update Personal Best
if particle(i).Cost<particle(i).Best.Cost

            particle(i).Best.Position=particle(i).Position;
            particle(i).Best.Cost=particle(i).Cost;

% Update Global Best
if particle(i).Best.Cost<GlobalBest.Cost


    disp(['Iteration ' num2str(it) ': Best Cost = ' num2str(BestCost(it))]);

    w=w*wdamp;
     disp('PSO End')
end
BestSol = GlobalBest;
figure;
%plot(BestCost,'LineWidth',2);
semilogy(BestCost,'LineWidth',2);
xlabel('Iteration');
ylabel('Best Cost');
grid on;


BestSol= struct2table(BestSol);   %Convert Structure to Numeric
BestSol=vertcat(BestSol.Position);  % Taking only one field
xlswrite('C:\Input_Data\Best_Sol_Hybrid.xlsx',BestSol,'C4:T4');  % Writing to excell
```

**6. Result and Discussion**

Usually it is suggested to use larger diameters pipe to allow higher discharge with reduced velocity which minimizes the head loss. Using larger diameter pipes in WDN increase the cost of pipes and project cost. Smaller diameters pipe decreases the cost of pipe and project cost but increase the head loss resulting in lowering of head at next junction. Here optimization is required to select lowest possible values of the pipe diameter to maintain operating condition like minimum head loss, minimum head at junctions and maintaining required velocities in the pipes. In this study first the system is analyzed using EPANET 2.0 hydraulic solver to determine the pressure heads at each node and velocities at each pipe considering the calculated values of diameters. After the analysis the result is plotted in fig 3.1, 3.2 and 3.3. From the result it is observed that the diameters used in the analysis gives more discharges than required and hence decided to reduce the diameters in order to minimize the cost. To carry out further analysis we developed Hybrid algorithm (GA and PSO) and implemented in MATLAB 2016. We set 4 iterations for each run and carried out 20 runs using the diameters obtained from EPANET analysis. We got minimum cost value in the $8^{th}$ run and next minimum cost value in the $2^{nd}$ run. Based on the diameters availability and ease of layout arrangement $8^{th}$ run costs and diameters are decided as optimal and selected for implementation. The obtained results of $8^{th}$ run and $2^{nd}$ run is shown in fig 5 and 6.

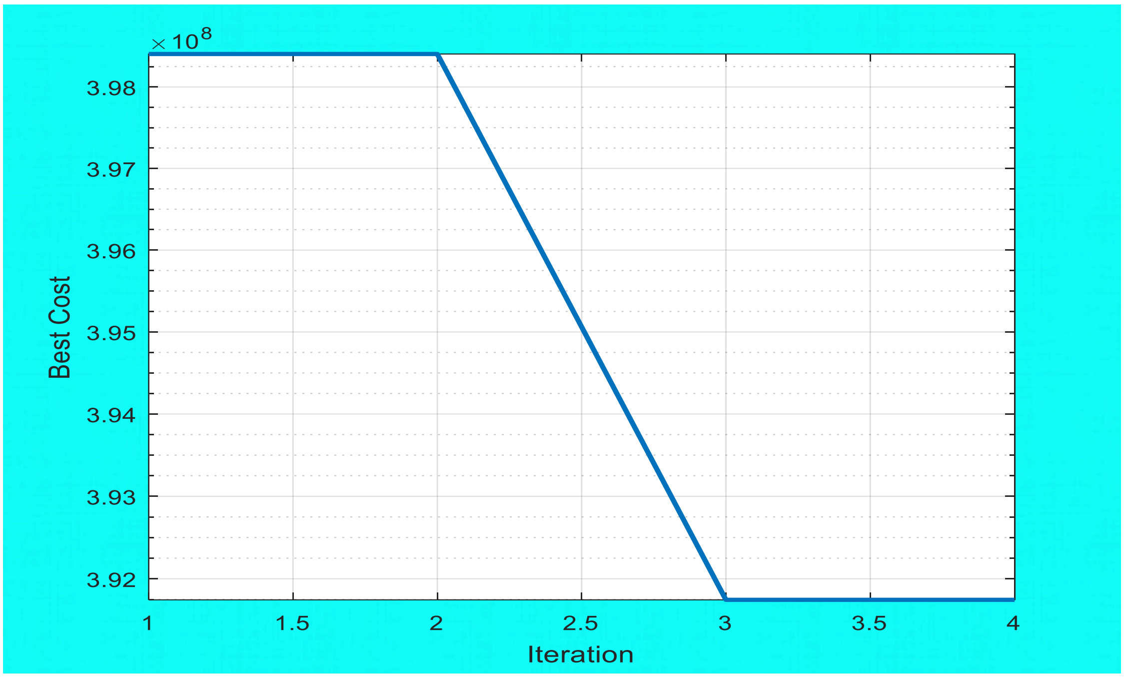


**Fig 5:** Run 8 Best cost v/s Iterations

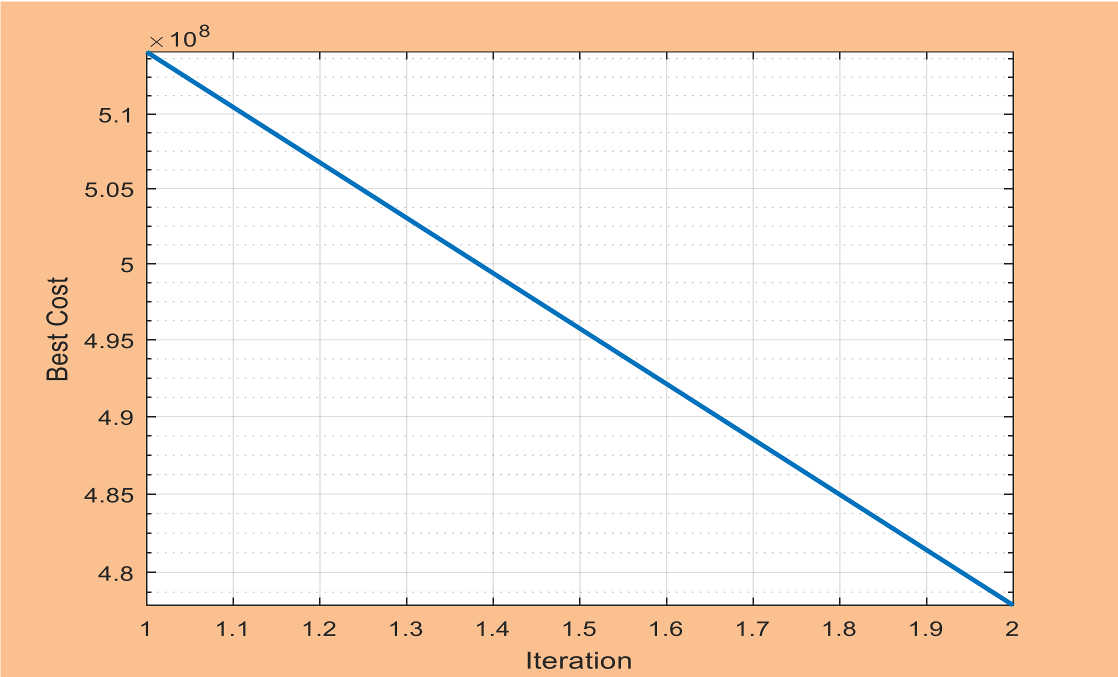


**Fig 6:** Run 2 Best cost v/s Iteration

**Table 1:** Pipe cost comparison for GA and Hybrid Analysis

| From | To | Pipe No | Length (m) | GA Analysis | | Hybrid Analysis (GA PSO) | |
|---|---|---|---|---|---|---|---|
| | | | | Diameter(m) | Cost(Rs) | Diameter(m) | Cost(Rs) |
| R | J1 | 2 | 1710 | 0.9 | 18485100 | 1.3 | 54560970 |
| J1 | J2 | 3 | 4342 | 0.4 | 19243744 | 1.1 | 76714456 |
| J2 | J3 | 4 | 1590 | 1.9 | 59679060 | 1.1 | 28092120 |
| J3 | J4 | 5 | 3893 | 0.55 | 27729839 | 0.9 | 42083330 |
| J4 | J5 | 6 | 2038 | 0.45 | 10970554 | 0.6 | 17159960 |
| J5 | J6 | 7 | 2789 | 0.25 | 7494043 | 0.25 | 7494043 |
| J6 | J7 | 8 | 1972 | 0.25 | 5298764 | 0.8 | 18359320 |
| J1 | T1 | 9 | 1314 | 1.1 | 23215752 | 0.2 | 2798820 |
| J2 | T2 | 10 | 2020 | 0.25 | 5427740 | 0.7 | 16059000 |
| J3 | T3 | 11 | 419 | 0.15 | 504476 | 0.45 | 2255477 |
| J4 | T4 | 12 | 3511 | 0.7 | 27912450 | 0.25 | 9434057 |
| J5 | T5 | 13 | 947 | 0.5 | 5973676 | 0.9 | 10237070 |
| J6 | T8 | 14 | 4342 | 1.0 | 63927266 | 0.5 | 23372986 |
| J6 | T6 | 15 | 1814 | 1.8 | 64663658 | 0.2 | 3863820 |
| J7 | T7 | 16 | 5762 | 0.25 | 15482494 | 0.25 | 15482494 |
| J7 | T8 | 17 | 2038 | 0.35 | 8127544 | 0.45 | 10970554 |
| T4 | T5 | 18 | 4563 | 0.35 | 18197244 | 0.35 | 18197244 |
| T6 | T7 | 19 | 1972 | 0.65 | 19088960 | 1.1 | 34841296 |
| Total pipe cost Rs. (Hybrid) | | | | | | | 391977017 |
| Total pipe cost (GA) | | | | | 401422364 | | |
| Reduction in pipe cost (Rs) | | | | | 2.4% | | |

After Hybrid Algorithm (GA and PSO) analysis it is observed that minimum required velocity in each pipe is maintained and also head loss is minimized. By carrying out this analysis we recommended lower values of diameters for the pipes. The result obtained by this analysis is compared with that of our previous GA analysis. Cost of pipe plays major role in minimizing the implementing cost of water distribution network projects. From the table 6.1 it is observed that there is a significant around 2.4% reduction in pipe cost and around 1% reduction in project cost compared to previously carried out GA analysis.

## 7. Conclusion and Future scope

Water supply systems are the major infrastructure of the society. This type of project is usually implemented for public service. Implementation cost of this type of projects is huge and is to be reduced. Pipe cost attains major percentage of project cost. Proper analysis of water distribution system is required. Optimization of water distribution network can be accomplished by many methods. In this study a Hybrid Algorithm based approach is used to analyze the real time WDN and achieved around 2.4% reduction in pipe cost and around 1% reduction in project implementation cost compared to GA analysis. Hybrid approach seems to be yield better result for this type of study. Further research can be carried out for optimization of diameters sizes by hybridization of different optimization techniques. Hybridization of Heuristic search methods like Genetic algorithms, Particle swam optimization, frog leaping algorithm, ant colony optimization etc. Complex water distribution network increases the maintenance cost and hence required to design simple networks. This can be carried by using GA, Fuzzy logic and other optimization techniques. Both existing and new WDN can be analyzed and redesigned. Optimized WDN reduce the cost and maintenance work.

**8. Acknowledgment**

The authors are grateful to The Principal, JSS Academy of Technical Education Bengaluru, for his support in carrying out this study. We acknowledge Head of Department and all Professors and staff of Mechanical Engineering department for their valuable comments and helpful suggestions which greatly improved the quality of this research.

**9. Data Availability Statement**

The data that support the findings of this study are available in the form of tables and graphs. Data related to Theoretical, EPANET and GA and Hybrid analysis are stored in the file. Related data of this research can be viewed or downloaded from the url: https://data.mendeley.com/drafts/jdhh62ww3p?folder=841440ef-52e9-4696-bafb-ff7ddb15f409
http://dx.doi.org/10.17632/jdhh62ww3p.1

These can be available on request from the corresponding author, [Prakash Hanumanthappa]. The data are not publicly available as further research has to be carried using data as a part of improvement.

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