

# **RESEARCH ARTICLE**

## HYDRAULIC NETWORK MODELING AND OPTIMIZATION OF PUMPING SYSTEMS.

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## ..... Manuscript Info

#### Abstract

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Key words:-Hydraulic modeling, EPANET, pumping systems, performance evaluation, energy efficiency, piping system, energy saving.

..... Pumping systems can be modeled as a network of pipes, valves, reservoirs and pumps. Network modeling aids performance evaluation of pumping systems. Key components of the system are taken into consideration and as a result, their behavior can be analyzed inside a network. Only pump efficiency is not a sufficient parameter to determine the performance of a pumping system, but other factors like contribution of pipes in resistance to flow due to size, pressure drop, etc. are also crucial to study for overall impact on the performance of a pumping system. There are significant opportunities for energy saving in such networks which can be explored if studied as a system altogether. This paper will elucidate such a hydraulic study based on municipal water distribution system modeled and evaluated in EPANET.

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## **Introduction:-**

Pumping systems are installed to transport / lift fluids from a source to a discharge point. In order to achieve this, there is a network of pumps, pipelines, valves, reservoirs etc. The fluid to be lifted / transported is supplied kinetic and potential energy by a pump. The only component of a pumping system that is supplied with energy is the pump (to the impeller driven by a driver); however, only pump's efficiency cannot determine the performance of the system as a whole. But other components do play an important role in determining the overall performance of the network. Their behavior is also crucial to analyze the network and explore for scope of energy savings; as pumping systems account for 20% of world's electricity consumption. This draws immediate attention on performance study of such networks.

EPANET (open source network tool) is developed by the United States Environmental Protection Agency, a very popular and extensively used package for modeling of hydraulic networks with the help of components such as reservoir, pumps, valves, pipes, nodes and tanks. It helps in building a network of such pumping system and evaluates their performance based on the parameters fed. This will give an idea of each component's behavior in the network of the pumping system. The components can be placed as per required design parameters, capacity and be connected with each other to form a network. When the simulation is run, results can be obtained in the form of performance parameters for each component based on the existing design system, which can be compared with proposed design system and studied for exploring the scope of energy savings and better operational practices.

## **Procedure:-**

A municipal water distribution station (WDS) is undertaken for hydraulic study purpose. The practice to study the network is, first to collect the available data from site viz. details regarding pumping capacity, piping and instrumentation, power supply, operational practices of pump, discharge details and delivery lines and points, their distance from pumping station, facilities for measurements etc. Then the measurements are carried out for the output of pump (suction, discharge pressure and flow rate of pump) and the input of pump (motor input power). The outcome of the study would determine the performance of the system based on the measurements, site environment and conditions.

## Site details:-

The WDS has four pumps (submersible, vertical turbine type) of 200 HP, driven by 150 kW motors, having a rated flow of 918 cubic metre per hour (CMH) and rated head of 43 metre. The operating practice is to run all the pumps together for 8 hours a day (twice for 4 hours). The flow reducing valves (FRV) of 450 mm diameter are installed on delivery side of pumps. The pumps are located inside an underground reservoir of capacity 12 million litres, (which is fed from an intake well inside a local river water source) pumping the water to nearby localities using a 60 km network of pipelines. The suction pipelines of pumps are of 2 metre length, 450 mm diameter.

#### Hydraulic model:-

The hydraulic network simulation is done on EPANET platform, using an underground reservoir (R1), 4 pumps (P1-P4), 4 valves (V1-V4), 13 delivery nodes (D1-D13), 17 pipelines, viz.13 for delivery (L1-L13) and 4 for pump suction (F1-F4). The network developed as per actual configuration of the WDS is as shown in Figure 1 and detail as given in Table 1.



Figure 1:- Network developed in EPANET

Pump	Pipeline	Pipeline	Pipeline	Delivery	Pump	Pipeline	Pipeline	Pipeline	Delivery
No.	details	Diameter	Length	Point	No.	details	Diameter	Length	Point
	(Feed	(mm)	( <b>km</b> )			(Feed	( <b>mm</b> )	(km)	
	line)					line)			
Pump	L1	750	4.0	D1	Pump	L11 (L9)	350	0.75	D10
1					2				
	L2	750	10.0	D2	Pump	L4	900	7.5	D4
	L7 (L1)	500	6.0	D6	3	L5 (L4)	275	3.5	D13
	L8 (L1)	500	7.0	D7	Pump	L6	900	5.3	D5
Pump	L3	750	3.5	D3	4	L12 (L6)	275	3.3	D11
2	L9	275	2.5	D8		L13 (L6)	350	5.7	D12
	L10 (L9)	350	0.75	D9					

Table 1. Details of	ninelines and t	he numps	feeding	with delivery	node
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#### Existing condition analysis:-

In order to calculate the efficiency of the pump, the performance parameters of the pump must be measured as per standard practices. These measurements should not be instantaneous and hence must be taken as an average of measurements over some span of running hours. In this case, the measurements are taken for pressure, flow and power for one hour for each pump and their efficiency is calculated using Eq. (1). Using the average values of one hour measurements, the efficiency is obtained for each pump as summarized in Table 2.

Pump efficiency, 
$$\eta_p = \frac{Q * h * g * \rho}{3.6 * 10^5 * \eta_m * P} * 100$$
 Eq. (1)

Where,

Q = Flow rate of fluid (in m<sup>3</sup>/hr or CMH)

- h = Total head developed by pump (in m)
- g = Gravitational acceleration (in m/s<sup>2</sup>)
- $\rho$  = Density of fluid (in kg/m<sup>3</sup>)

 $\eta_m$  = Motor efficiency

P = Power input to motor

Table 2 Weasared performance parameters of pump and then calculated efficiency							
Pump	Pressure	head	Flow rate (CMH)	Power o	consumed	Efficiency (%)	
	developed (m)			( <b>kW</b> )			
P1	36.24		821	132.96		67.21	
P2	36.21		799	138.91		62.56	
P3	28.18		751	132.87		47.84	
P4	28.89		900	139.60		55.94	

#### Table 2:- Measured performance parameters of pump and their calculated efficiency

The measurements taken at site are fed into the EPANET network module in order to evaluate overall performance of the hydraulic system. Per unit cost of electricity used for calculating the operating cost is taken to be as Rs. 6.25/kWh, the density of water was found out to be 992 kg/m<sup>3</sup>, the motor efficiency was calculated after conducting the no-load test to find out fixed losses and tested under full-load for copper losses, efficiency was calculated to be 90% as per de-rating factor and the acceleration due to gravity is taken as  $9.81 \text{ m/s}^2$ . The pumps are operated for 8 hours a day which makes the per-day utilization / usage factor of 33%. The results of the simulation are given in Table 3.

Pump	Percentage	Efficiency (%)	Energy Index	Power consumed	Cost/Day (Rs.)
	Utilization (%)		(kW-hr/m <sup>3</sup> )	( <b>kW</b> )	
P1	33.33	67.21	0.16	132.96	6648.22
P2	33.33	62.56	0.17	138.91	6945.42
P3	33.33	47.84	0.18	132.87	6643.25
P4	33.33	55.94	0.16	139.60	6979.86
				TOTAL	27216.75

Table 3:- Results of existing conditions of the network

EPANET can calculate the head-loss for a given network using Hazen-Williams (HW) formula, Darcy-Weisbach (DW) formula or Chazy-Manning (CM) formula. The head-loss for this network is calculated using the Hazen-Williams (HW) formula as given in Eq. (2).

$$Head - Loss = \frac{10.67 * Q^{1.852} * l}{C^{1.852} * d^{4.874}} \quad (in m)$$
 Eq. (2)

Where,

- Q = Flow rate of fluid (in m<sup>3</sup>/s)
- $\overline{l}$  = Length of pipeline (in m)
- C = Roughness coefficient of pipe

d = Diameter of pipe (in m)



The pressure / head loss of the system components are as shown in Figure 2.

Figure 2:- Pressure at different nodes and head-loss of different links

The velocity of water in pipelines is an important parameter to evaluate the frictional losses, flow through each link and the unit head-loss as per the existing conditions modeled in EPANET are summarized in Table 4.

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Link ID	Flow	Velocity	Unit Head	Link ID	Flow	Velocity	Unit Head						
	(CMH)	(m/s)	loss (m/km)		(CMH)	(m/s)	loss (m/km)						
L1	531	0.33	0.25	L10	135	0.39	0.81						
L2	290	0.18	0.08	L11	123	0.36	0.68						
L3	799	0.50	0.53	L12	237	1.11	7.38						
L4	751	0.33	0.19	L13	163	0.47	1.14						
L5	223	1.04	6.59	F1	821	1.43	6.67						
L6	900	0.39	0.27	F2	799	1.40	6.35						
L7	325	0.46	0.72	F3	751	1.31	5.66						
L8	128	0.18	0.13	F4	900	1.57	7.91						
L9	258	1.21	8.63										

Table 4:- Flow, velocity, unit head-loss for individual links

These parameters are very useful in order to know about the operating conditions of the network. They determine the scope of improvement in network operation and the possibilities of future expansions or modifications as per the application demand. It is important to know how the network operates and in what condition so as to explore any avenue for optimization.

The velocity of water in each pipeline and the pressure available at different nodes / delivery points is as shown in Figure 3.



Figure 3:- Pressure at different nodes and velocity of water at different links

#### **Observations:-**

The installed pumps are approximately 5-6 years old as per the information gathered and they are not undergoing any regular scheduled maintenance as required for better operation. The calculated average efficiency for individual pump is very poor for Pump no. 3 and 4 (48% and 56%) and satisfactory for Pump no. 1 and 2 (in range of 62-68%). The performance of system can be judged based on following observations -:

- 1) The condition of impeller of Pump No. 3 and 4 might be deteriorated; which is supported by the fact that the pump is producing only 28 m, due to which it is not able to develop its rated hydraulic power.
- 2) Pump No. 3 and 4 are operating at the actual head of 28 m, and Pump No. 1 and 2 are operating at actual head of 36 m, against the rated head of 43 m for all pumps.
- 3) The velocity of water in all the pipelines was less than 2.0 m/s, which is satisfactory as per the design standards, as high velocity may incur more frictional loss.
- 4) The velocity are in limits, however, the pipelines L5, L9 and L12 have high unit head-loss due to the fact that the size of the pipelines are smaller (275 mm).
- 5) The pipelines L5, L9, L12 should be replaced with 350 mm pipes so that the head-loss is reduced as well as the loss-coefficient," C" used in Hazen-Williams equation, will increase and hence overall head-loss of pipeline will also reduce since the frictional losses would decrease.
- 6) The demand nodes D8, D13 and D11 are affected due to the poor performance of these pipelines, the pressure of water available at these nodes is very low as compared to other demand nodes.
- 7) Due to low pressure at demand nodes, the locality may not receive sufficient supply. Also if demand increases, the pump may not be able to deliver up to that node.
- 8) The pressure-head loss in pipelines is leading to waste of energy that is provided to the fluid by the pump and hence must be dealt with.

#### Impact of Change in Pipeline on the Network:-

From hydraulic network simulation, it is evident that pipelines L5, L9, L12 have significantly high head-loss per unit length, if the diameter of suction pipes are increased from 275 mm to 350 mm for all the pipelines, it would reduce the frictional head loss in pipelines and increase the pressure of water supplied at the farthest end node as evident from Figure 4. This simulation is showing significantly how this measure would improve the water distribution, also taking into consideration the future expansion of the network and increase in water demand to study / examine network behaviour in conditions of enhanced operating capabilities of the system.



Figure 4:- Pressure at different nodes and unit head-loss at different links after changing pipelines

The change in pipeline diameter would yield results as obtained from the simulation given in Table 5.

Link ID	Flow (CMH)	Velocity (m/s)		Unit Head loss (m/km)	
		Old pipe	New pipe	Old pipe	New pipe
L5	223	1.04	0.64	6.59	0.96
L9	258	1.21	0.74	8.63	1.26
L12	237	1.11	0.68	7.38	1.08

Table 5:- Comparison of velocity of water and unit head-loss in existing and changed pipelines

The results clearly show that the velocity of water in pipelines is significantly reduced and hence the frictional head loss is reduced as well. The effect of change in pipe dimension on pressure is also quite significant on the immediate demand node corresponding to the pipe and also increases the pressure on the last node of supply as the head loss for other pipeline is fixed. The results show that pressure at delivery node D13, D8 and D11 from pipeline L5, L9 and L12 respectively, is changed significantly due to change in pipe dimension and because of that, the end delivery nodes (D13, D8 and D11) have an increased pressure of supplied water. The difference in values of pressure at affected nodes is shown in Table 6.

Pipeline ID	Node ID	Pressure (m)		
_		Old value	New value	
L5	D13	3.50	23.18	
L9	D8	13.60	32.01	
L12	D11	2.86	23.63	

Table 6:- Comparison of pressure values based on existing pipelines and changed pipelines

However, these measures are suggested only for better operation of the system, they don't affect energy consumption of pumps or their efficiency; but in case of future expansion or increase in number of connected demand nodes, higher pressure head availability at nodes would be advantageous.

#### Network Optimization Measures (N.O.M.):-

In order to improve the performance of the network, there are 3 different possibilities of optimization. The feasibility study of such optimization measures is done and it is recommended to implement suitable measures as per the requirements of application. Any one out of the three measures can be selected as per the requirement, which would improve performance of the network as well as reduce the energy consumption of overall network, are as follows:

- 1) Replacement of Pump No. 3 and 4 by energy efficient pumps and Over-hauling and Corro-coating can be done for Pump No. 1 and 2.
- 2) Construction of one overhead tank at the WDS and supplying tank with water through one existing pump (1 existing Pump of 200 HP).
- 3) Construction of one overhead tank at the WDS and supplying tank with water through two new smaller rating pumps (2 new Pumps of 100 HP each).

## Techno-Economic feasibility study of N.O.M .:-

## [1.A] Replacement of Pump No. 3 and 4

First measure suggests replacement of Pump No. 3 and 4 with energy efficient pumps and Overhauling and Corrocoating of Pump No. 1 and 2. It is evident from the observations supported by calculations, that the Pump No. 3 and 4 are highly inefficient pumps and should be replaced with energy efficient pumps available in market with an efficiency of around 70%.

## [1.B] Overhauling and Corro-coating of Pump No. 1 and 2

The Pump No. 1 and 2 are having satisfactory efficiency of 66% and 63% respectively. This indicates the pump can perform better if they are maintained properly. Overhauling of pumps would include inspection of various components of pump and then diagnostic of problems that prevent pump from operating at its best efficiency point (BEP). If required impeller can be trimmed for matching system head-flow requirements and hence lead to improvement in pump performance and reduced energy consumption of pump.

Corro-coating is a resin based chemical material applied on metals / alloys that are exposed to or are in contact with water / moisture. In this case, impeller and its casing might have been affected due to corrosion effect. The resin based chemical is applied as a coating to the internal parts of the pump.

Together these measures would increase the efficiency of the pump by 5% approximately in actual against claimed 10% by the manufacturer of resin coating material. It is most simple optimization measure. There is no requirement to make major changes in network component. Only by improving pump performance, the network performance is optimized.

The existing pumping network is estimated to work on the following improved parameters after implementation of suggested measures as shown in Table 7.

Pump	Pressure head developed (m)	Flow rate (CMH)	Power consumed (kW)	Efficiency (%)
P1	36.34	850	128.33	72.30
P2	37.13	820	132.84	68.84
P3	29.24	880	109.74	70.43
P4	28.48	920	109.67	71.76

**Table 7:-** Improved pump performance parameters after implementation of energy saving measures

It is also suggested for better performance and system operation, overhauling and maintenance of pumps should be done regularly and the system must be diagnosed properly in order to identify any problems, issues or factors that lead to degradation of efficiency of the pumping system. Timely maintenance of pipes is also an important factor and so is the cleaning of the strainer of the pump which is present on the suction side in order to filter out sludge / solid particles / waste, if present in the reservoir.

The improved flow and pressure of the network after implementation of energy saving measures is projected to be as shown in the network in Figure 5.



Figure 5:- Improved pressure at different nodes and flow rate of water at different links

The overall efficiency of the network has improved and is evident from the calculated results as given in Table 8.

Pump	Percentage	Efficiency (%)	Energy Index	Power consumed	Cost/Day (Rs.)
	Utilization (%)		(kW-hr/m <sup>3</sup> )	( <b>kW</b> )	
P1	33.33	72.30	0.15	128.33	6416.66
P2	33.33	68.84	0.16	132.84	6591.91
P3	33.33	70.43	0.12	109.74	5487.21
P4	33.33	71.76	0.12	109.67	5483.43
				TOTAL	23979.21

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Table X. Calculated	results of network	atter implemen	tation of energy	v saving measures
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The summary of calculations for economic feasibility of implementing these measures is shown in Table 9.

Pump	Existing Power (kWh)	Proposed Power (kWh)	Annual Energy Savings (kWh)	Annual Monetary Saving (Rs.)	Estimated Investment (Rs.)	Simple Payback Period (years)
P1	132.96	128.33	13,520	84,497	3,00,000	3.55
P2	138.91	132.84	17,724	1,10,778	3,00,000	2.71
P3	132.87	109.74	67,540	4,22,123	14,00,000	3.31
P4	139.60	109.67	87,396	5,46,223	14,00,000	2.56

Table 9:- Proposed energy savings and calculated economic aspect of implementing energy saving measures

The total energy savings from these measures for present operational practice, is projected to be 1,86,180 kWh and in monetary terms, Rs. 11.65 lakh with an estimated investment of Rs. 34 lakh and average simple payback period of approximately 3 years.

# [2] Construction of an Overhead Tank and pumping with an Existing Pump (1 x 200 HP):-

In current scenario, the WDS is not having any facility or infrastructure to supply water to the locality for 24 hours. The water is supplied in 4 hours duration for 2 times a day and hence only 8 hours a day. If an overhead tank is constructed in the premises of the WDS and a existing pump of 200 HP after overhauling, (in order to improve its efficiency) is used to supply water to the tank and then the tank could supply water to the network, it would not only reduce the no. of pumps operating and save energy, but also provide 24 hours of water supply to the locality. As per the data available from the network, in order to cater the demand of the locality, the capacity of an overhead tank should be approximately 45 Lakh litres in order to meet the demand for 24 hours. According to the capacity and pressure head requirement of network, the dimensions as well as the elevation required for the concrete tank are obtained to be as given in Table 10.

 Table 10:- Overhead Tank Specifications

Tank Capacity / Volume	Tank type	Tank dimensions (in m)		
(In Lakh litres)		Radius	Height	Elevation
45	Cylindrical	12	10	18

The costing of construction of an overhead tank and the civil, plumbing, electrical costs are obtained as a method of weighted average as given in Table 11.

Table 11:-	Overhead	Tank	Costing	Estimation
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Capacity	Cost	Bifurcation of Cost	Cost	Percentage of Total
(in lakh litres)	(in Rs. lakh)		(in Rs. lakh)	Cost (%)
45	238.81	Civil	200.12	83.80
Weighted Average Cost (Rs./ litre)		Plumbing	30.57	12.80
		Electrical	5.25	2.20
5.28		Miscellaneous	2.87	1.20

In this N.O.M., only one pump of 200 HP is supplying the water to the tank through a pipeline as per the level of water inside the overhead tank. This measure would save energy in terms of pumping requirement and the overhead tank would provide the network with 24 hours of un-interrupted water supply. In order to simulate this inside the network built in EPANET, the demand of each node over 24 hours has been distributed into average hourly demands with variable multiplying factors. This gives idea about the hourly performance of network as well as improves the distribution capacity of network by providing un-interrupted supply.

The modified network as simulated in EPANET, shows the pressure on individual nodes and flow in individual links as shown in Figure 6.



Figure 6:- Pressure at nodes and Flow at links of modified network with overhead tank

The performance of the pump after the overhauling, working at improved efficiency of around 72% works on the estimated performance parameters as given in Table 12. The pump is required to run for 12 hours during the day in order to pump water to the overhead tank as per demand and water level variations.

<b>Table 12:-</b> Existing Pump performance as estimated after Overhauli	mance as estimated after Overhauling
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Pump	Pressure head developed (m)	Flow rate (CMH)	Power consumed (kW)	Efficiency (%)
P1	23.12	1527	140.82	72.87

The techno-economical aspects of this N.O.M. as calculated in EPANET are as given in Table 13.

			01				
Pump	Percentage	Efficiency	<b>Energy Index</b>	Average	Power	Maximum	Cost/Day (Rs.)
	Utilization	(%)	(kW-hr/m <sup>3</sup> )	consumed (	kW)	Power	
	(%)					consumed	
						( <b>kW</b> )	
P1	50	72.87	0.11	103.30		140.82	7747.50

Table 13:- Techno-Economical evaluation of existing pump

A summary of feasibility study and economical advantages of this N.O.M. are projected to be as given in Table 14.

 Table 14: Techno-Economical feasibility of N.O.M.

Existing	Proposed	Savings	Annual	Distribution of		Total	Simple
Power	Power	(in	Monetary	Investment		Investment	Payback
consumption	consumption	kWh/day)	Savings	(in Rs. Lakh)		(in Rs.	Period
(in kWh/day)	(in kWh/day)		(in Rs.			Lakh)	(years)
			Lakh)				
4354.72	1239.60	3115.12	71.06	Overhead	Existing	242	3.40
				Tank cost	Pump		
					Overhauling		
					cost		
				238.81	3.00		

As per the calculations, it is showing an annual energy saving of 11,37,020 kWh, which is Rs. 71 lakh in monetary terms, after implementing the measure with investment of Rs. 242 lakh, gives a simple payback period of approximately 3.4 years.

## [3] Construction of an Overhead Tank, pumping with Two 100 HP Pumps (2 x 100 HP):-

In this N.O.M., two pumps of 100 HP are used to supply water to the overhead tank. The advantage of this measure would be the availability of one pump in case breakdown of another, which would ensure reliable supply of water to network (which could not be possible in previously suggested N.O.M.), though it would take more working hours for a single pump. In current scenario, these two smaller rating pumps together operate for 13 hours a day. The pressure at nodes and flow at links is as given in Figure 7.



Figure 7:- Pressure at nodes and Flow at links of modified network with overhead tank and two pumps

The new pumps are working at an efficiency of around 71% and estimated performance parameters as given in Table 15. The pumps are operating for 13 hours during the day to pump water to overhead tank as per demand and water level variations.

Table 15:- N	ew Pump	performance	parameters as estimated
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Pump	Pressure h developed (m)	iead	Flow rate (CMH)	Power consumed (kW)	Efficiency (%)
P1	23.12		700	68.87	70.35
P2	23.03		770	71.98	71.61

The techno-economical aspects of this N.O.M. as calculated in EPANET are as given in Table 16.

Table 16:- Techno-Economical evaluation of new pump installations

Pump	Percentage	Efficiency	<b>Energy Index</b>	Average Power	Maximum Power	Cost/Day
	Utilization (%)	(%)	(kW-hr/m <sup>3</sup> )	consumed (kW)	consumed (kW)	( <b>Rs.</b> )
P1	54.17	70.35	0.09	46.96	66.87	3815.50
P2	54.17	71.61	0.09	51.10	71.98	4151.88
					TOTAL	7967.38

A summary of feasibility study and economical advantages of this N.O.M. are projected to be as given in Table 17.

Table 17:- Techno-Economical feasibility of N.O.M.

Existing	Proposed	Savings	Annual	Distributio	n of	Total	Simple
Power	Power	(in	Monetary	Investment		Investment	Payback
consumption	consumption	kWh/day)	Savings	(in Rs. Lak	<b>h</b> )	(in Rs.	Period
(in kWh/day)	(in kWh/day)		(in Rs.			Lakh)	(years)
			Lakh)				
4354.72	1274.78	3079.94	70.26	Overhead	New Pump	260	3.71
				Tank cost	Installation		
					cost		
				238.81	20.80		

As per the calculations, it is showing an annual energy saving of 11,24,178 kWh, which is Rs. 70 lakh in monetary terms, after implementing the measure with investment of Rs. 260 lakh, gives a simple payback period of approximately 3.7 years.

## Summary:-

The summary of all Network Optimization Measures (N.O.M.) are as given in Table 18. It gives a comparison of different optimization techniques for a water distribution network of WDS. The choice of most suitable option can be done on the basis of the requirements of the application. Also it depends on various factors like reliability of network supply, power consumption, scope of energy savings, amount of investment, suitability for the site and various other considerations are to be kept in purview of the subject while undertaking the hydraulic study of a large and complex network.

Sr. No.	DescriptionofNetworkOptimizationMeasure	Annual Savings (in kWh)	Annual Monetary Savings	Investment (in Rs. Lakh )	Payback Period
	(N.O.M.)		(in Rs. Lakh)		(years)
1	Replacement of Pump No. 3,4	1,86,180	11.65	34.00	2.92
	and Overhauling of Pump No.				
	1,2				
2	Construction of an Overhead	11,37,020	71.00	242.00	3.40
	Tank and using one existing				
	(200 HP) pump to supply water				
3	Construction of an Overhead	11,24,180	70.00	260.00	3.71
	Tank and using two new smaller				
	(100 HP) pumps to supply water				

Table 18:- Summary and Comparison of all N.O.M.

# **Conclusion:-**

The hydraulic model helps in clearly mapping the system components and shows how these components perform in the system. It not only finds the limitations of existing system, but also shows the possibilities of efficient technology implementation and their benefits. Extensive amount of useful data can be obtained and more complex systems can be easily understood with the help of hydraulic models. The pressure at each node, the flow in each pipeline, demand based supply can all be well-simulated in this model.

The model helps in understanding the overall performance of the pumping systems and is a very useful tool to develop and simulate the proposed conditions / changes and analyze the system accordingly for any hydraulic network. The network of any size or configuration is easily modelled in this tool and then it can be diagnosed for any problems / drawbacks inside the system. This gives scope for optimization of network and it can be simulated before implementing in actual in order to get an idea of how the system would work under different configurations / conditions. It is very important to study the feasibility of such measures that can optimize measures and improve or enhance the performance of the network, as evident from the network modelled in this case.

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