Hydraulic analysis and cost optimization of water network by using the EPANET software

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Abstract

EPANET software can do a hydraulic analysis of the water network. In addition, the software can run with time duration which means that the result can be got as function in time. In this paper, a hydraulic analysis of water network of town of about 7000 population under an area of 0.6 km^2 and 2125 m^3/day water demand is done by using the EPANET software. Also, an optimization is done to minimize the energy cost of the electricity by the investigation of what minimum level that the tank discharge water without using a pump. Therefore, nine hours make the network operate by gravity main and 15 hours by pumping main. That can be done only by EPANET software result table that show how many hours that can make the pump off instead of using it the whole day. The energy cost minimized by 38 %.

Keywords: EPANET, hydraulic analysis, network, cost, pump

1. Introduction

Design of water distribution network is based on the minimum cost consideration not only the hydraulic analysis. Pumping electricity and pipe materials are the two main parts that affect the capital cost of the network (Prabhata, 2007). "Hydraulic analysis and optimization using EPANET (the U.S Environmental protection agency) contains a state- of – art hydraulic analysis engine that has no limit on the size of the network. It use Hazen- Willimas, Darcy- Weisbach or Chezy- manning formulas"(Lewis,2000). In this paper the hydraulic analysis steps of EPANET software will be done to tabulate the result of the of the flow properties at the nodes and the pipes as a function of time. Also, from these results an tank level and nodal pressure optimization to minimize the cost of the pumping energy.

Yungyu Chang & eta al (2018) concluded that the cost of energy can be reduced by the idea of reducing the supplied water demand once the price of the electricty is high and increasing it when the price is low by using strage tanks. Vogelesang (2009) quantitatively discussed the cost can be reduced to 27 % with a 10 % decreasing the speed of the pump. Viholainen et al (2013) studied that using two pump in parallel, two frequency converters, and one programmable logic controller which make a high efficiency that lead to low power cost. Ioan Sarbu (2016) described four strategies to get a high energy efficiency: variable control system speed according to water demand, pumped storage tanks. Elevated storage tanks floating on the system, and pumping station integrated in the network.

Morfecai (2009) concluded that the energy can be saved by storing the excess water in reservoirs during the off peak period, and supplying from the reservoir during the peak period while reducing the pumps production at this time

This paper will cover to main approach: the first one illustrates the hydraulic analysis which starting with defining the network under study, importing map from AUTOCAD, inserting data to the network, and getting the results. The second approach is the optimization of the time series between tank level and the nodal pressures by investigating the results that tabulated from the first approach. Finally the results of the two approaches will be showed and discussed in the last sections.

2. The case study

The network is for Alwater town in Tobruk- Libya. It contains of 1025 houses, 1 school, 1 Masjid, and 2 facilities. It covers area of 0.6 Km^2 and slop of 0.05 (2.8^o). The demand/ day is shown in table (1).

Table (1). Demands per day

Demand type	Demand/ person L/s	Person/ day P/day	Total demand m^3/day
Person	300	7175	2152.5
Masjid	25	400	10
Facilities	25	40	1

3. The method

3.1 The network configuration

The town is drawn by AutoCAD software then exported to Google Earth to specify the elevations. The drawn town then exports to EPANET software to start drawing the network. The google earth image of the town is shown in figure (1a) and the network is shown in fig (1b).

Figure (1a) Google earth image of the town under study

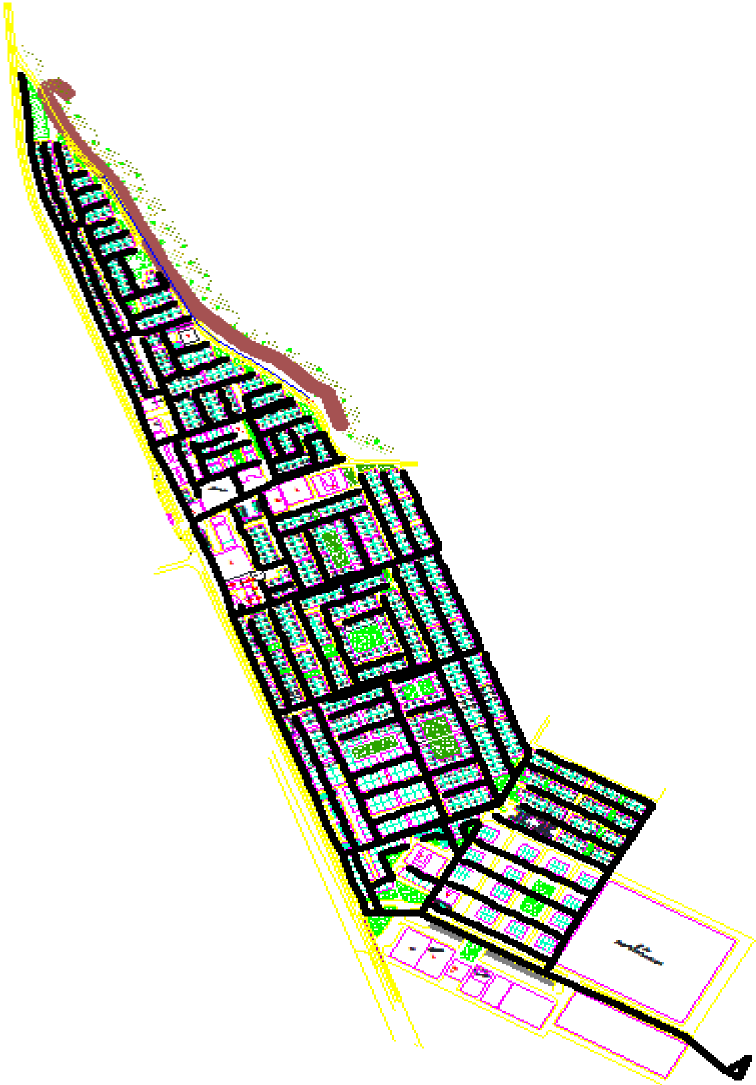

Figure (1b). The network under study

3.2 The analysis of the network

3.2.1 Link Editing window (pipe dimension and pump property)

In EPANET pipes and pumps are called links. The diameters of pipes (change from 150,200, and 300 mm) , the lengths (getting from AutoCAD software), roughness, and pipe status (open or closed) are editing as shown in figure (2).

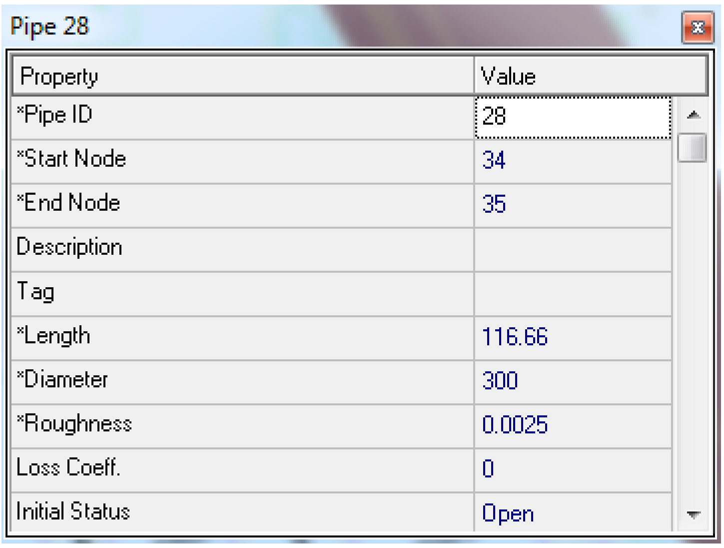

Figure (2). Pipe diameters and length

For the pump, pump selection curve and pump property (speed, status, and price) need to be inserted as shown in figure (3)

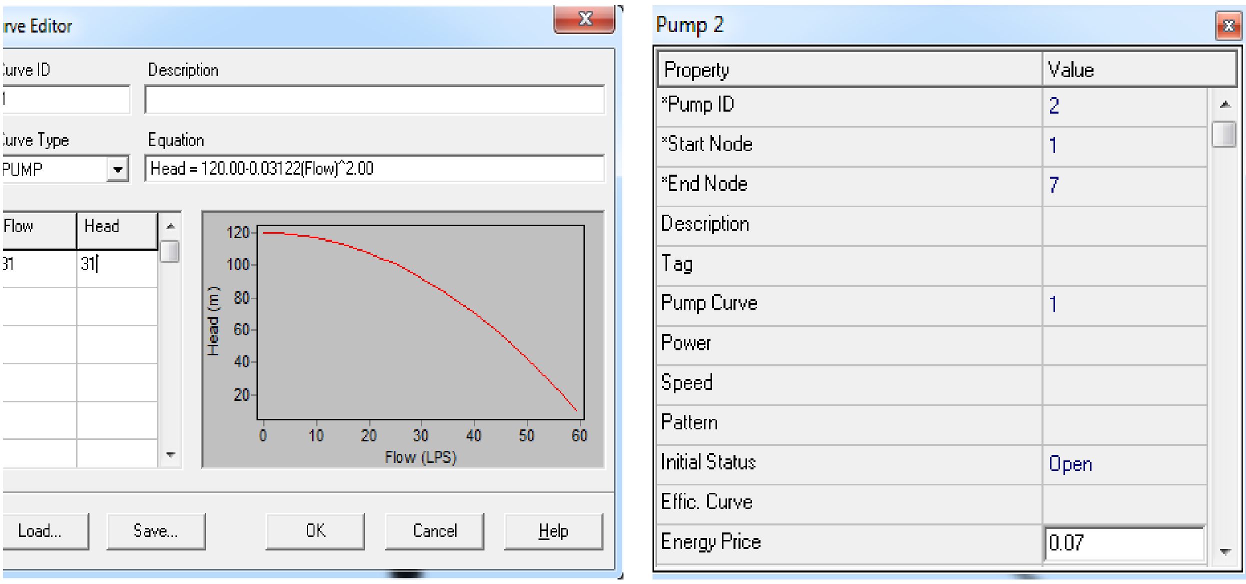

Figure (3). Pump selection curve and pump property

3.2.2 Junction editing

Nodes and Tanks are considered as a junction in EPANET. The node has the demands (L/s), and elevations as shown in figure (4) and Tanks has the elevation, the levels (maximum, initial, and minimum), and the diameter of the tank as shown in figure (5).

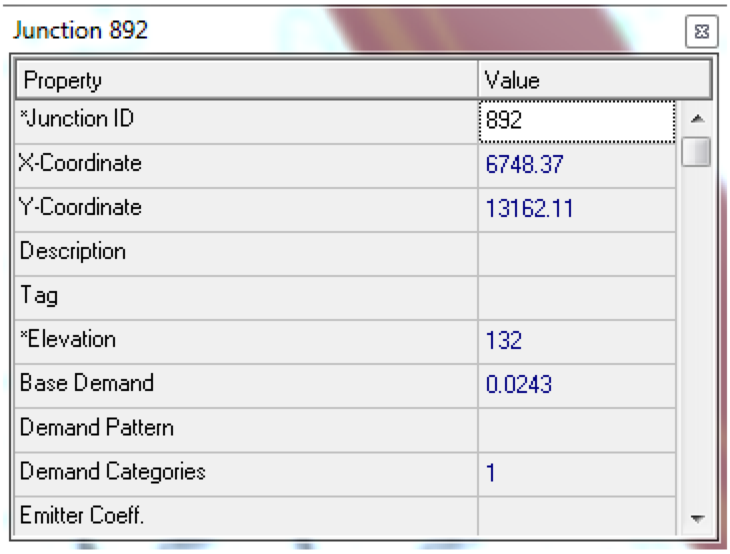

Figure (4). Node editing

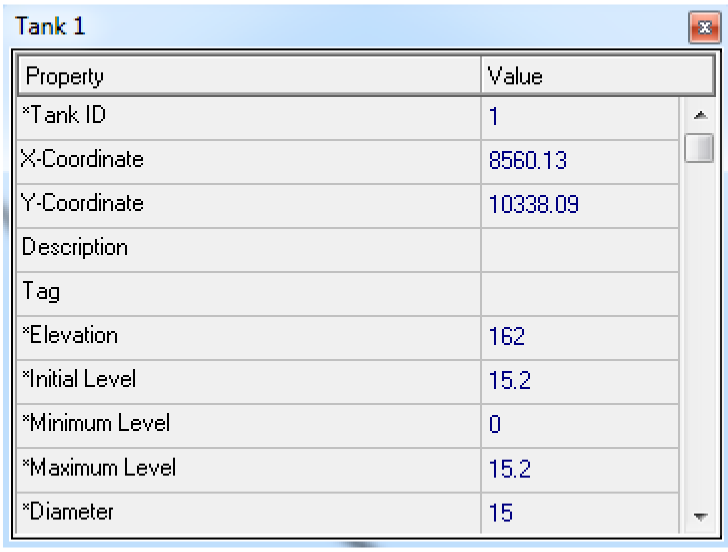

Figure (5). Tank editing

3.2.3 Time duration and the hourly map editing

In this window the time duration of network and the hourly viewed map are also edited as shown in figure (6)

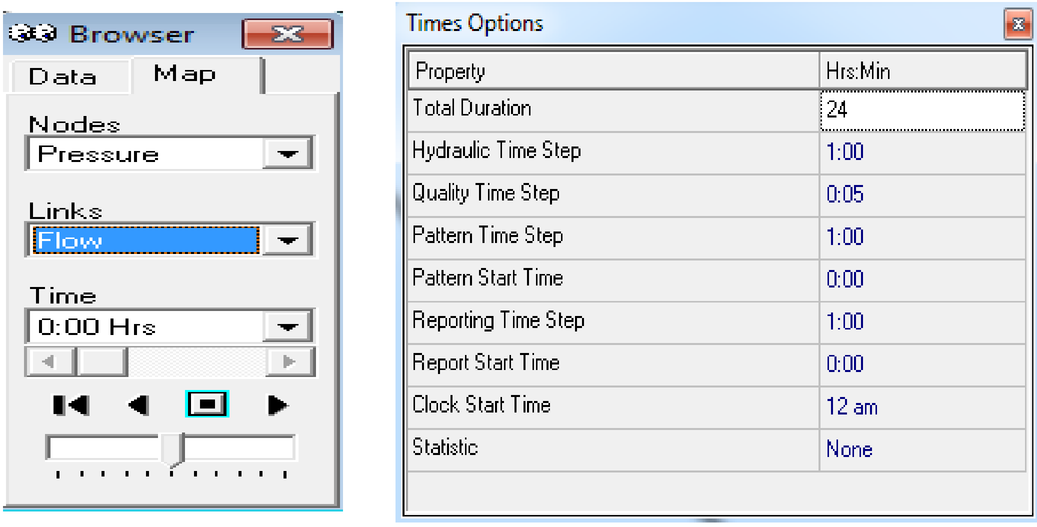

Figure (6). time duration of network and the hourly map

3.2.4 Units and fluid properties editing

The window in figure (7) shows the units and the fluid properties

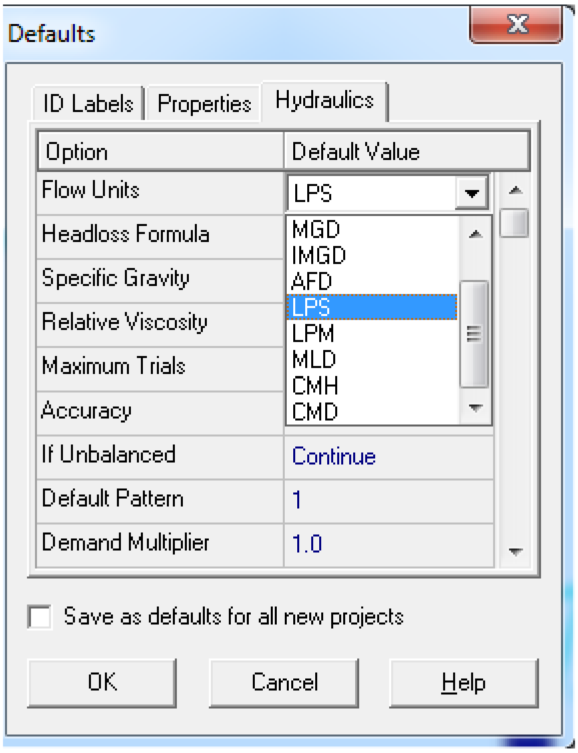

Figure (7). the units and the fluid properties

3.3 The optimization (cost energy reduction)

3.3.1 gravity main limitation

Pump must be used to overcome the negative pressures that absolutely seen in the majority of the network once only gravity main is used. However, the network can be operated without using pump for the first nine hours which it will save energy. So, EPANET is run to make the network operates partly by gravity until the negative pressure is at the minimum point (the minimum level of the tank- the maximum hour of the day that make the network operates gravitationally) and partly by using pump to increase the pressure of the network. Table (2) show the minimum hours that makes the tank work without pump. In other word the result of table (2) showed the first number of hours that the network should operate by gravity (no electricity price) and the number of hours that the network operate by pump.

Table (2). The negative pressure before inserting pump

Network Table - Nodes at 11:00 Hrs

Node ID	Demand LPS	Head m	Pressure m	Qı
Junc 8	0.00	159.80	-0.20	
Junc 9	0.00	158.86	-0.14	
Junc 10	0.00	158.78	-0.22	
Junc 11	0.00	158.64	0.64	
Junc 12	0.00	158.49	0.49	
Junc 13	0.00	158.41	1.41	
Junc 14	0.00	157.98	7.98	
Junc 15	0.00	157.79	9.79	
Junc 16	0.00	157.69	11.69	
Junc 17	0.00	157.62	11.62	
Junc 18	0.00	157.44	16.44	
Junc 19	0.00	157.41	18.41	
Junc 20	0.00	157.39	19.39	
Junc 21	0.00	157.34	19.34	
Junc 22	0.00	157.27	21.27	
Junc 23	0.00	157.24	23.24	
Junc 24	0.00	157.22	24.22	

3.3.2 pumping main operating (adding pump)

Pump is added to the network to work automatically by using EPANET control window as shown in figure (8).

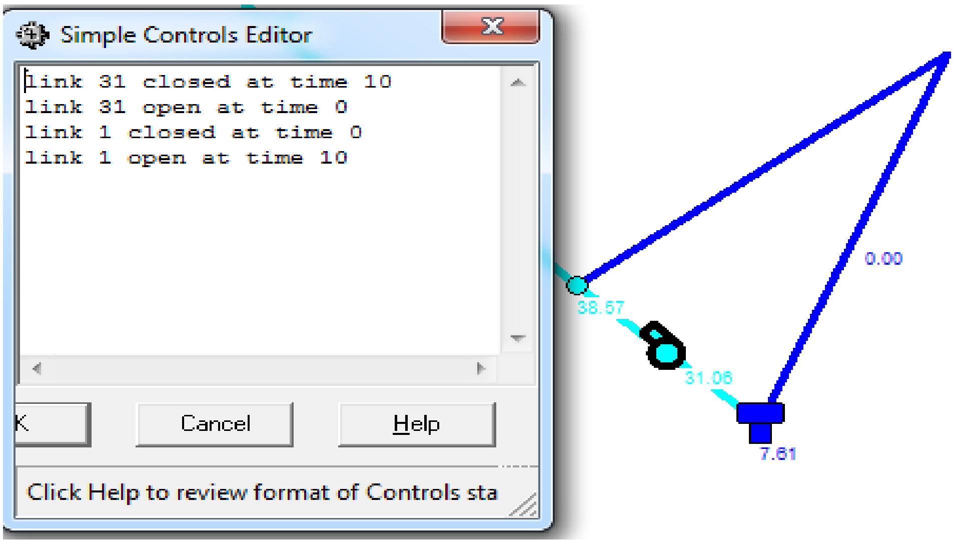

Figure (8). EPANET control code for pipe and pump operation

4. The results and discussion

4.1 The hydraulic analysis results

4.1.1 the nodal result at clock hour

Table (3) show the results of EPAET for node (766-732 as an example) at hour number 3 which has the head and pressure distributions for that nodes during the gravity operation. However, table (4) show the same parameter but in pumping main case at hour number12 as an example. As can be seen the pressures and heads increased once the pumping main is used.

Table (3). Elevation, base demand, head, pressure by gravity for node(766-732) at time 3:00

Network Table - Nodes at 3:00 Hrs

Node ID	Elevation m	Base Demand LPS	Head m	Pressure m
Junc 766	126	0.0486	174.53	48.53
Junc 612	126	0.0486	174.54	48.54
Junc 607	126	0.0243	174.54	48.54
Junc 577	127	0.0243	174.54	47.54
Junc 610	127	0.0243	174.54	47.54
Junc 757	127	0.0243	174.52	47.52
Junc 874	127	0.0243	174.52	47.52
Junc 863	127	0.0243	174.52	47.52
Junc 655	127	0.0243	174.53	47.53
Junc 873	127	0.0243	174.52	47.52
Junc 915	127	0.0486	174.52	47.52
Junc 857	127	0.0243	174.52	47.52
Junc 919	127	0.0486	174.52	47.52
Junc 920	127	0.0486	174.52	47.52
Junc 619	127	0.0243	174.54	47.54
Junc 789	128	0.0243	174.53	46.53
Junc 732	128	0.0243	174.53	46.53

Table (4). Elevation, base demand, head, pressure for node(766-732) at hour number12 (pumping main)

Network Table - Nodes at 12:00 Hrs

Node ID	Elevation m	Base Demand LPS	Head m	Pressure m
Junc 766	126	0.0486	199.80	73.80
Junc 612	126	0.0486	199.81	73.81
Junc 607	126	0.0243	199.81	73.81
Junc 577	127	0.0243	199.81	72.81
Junc 610	127	0.0243	199.81	72.81
Junc 757	127	0.0243	199.79	72.79
Junc 874	127	0.0243	199.79	72.79
Junc 863	127	0.0243	199.79	72.79
Junc 655	127	0.0243	199.80	72.80
Junc 873	127	0.0243	199.79	72.79
Junc 915	127	0.0486	199.80	72.80
Junc 857	127	0.0243	199.79	72.79
Junc 919	127	0.0486	199.80	72.80
Junc 920	127	0.0486	199.80	72.80
Junc 619	127	0.0243	199.81	72.81
Junc 789	128	0.0243	199.80	71.80
Junc 732	128	0.0243	199.81	71.81

4.1.2 The pipe result at clock hour

EPANET run at hour number3 for the pipes (2-16 as an example) to show the discharges that flow in that pipes, the head losses in that pipes, and the friction factor due to the viscosity of the water.

Table (5). Length, diameter, roughness, pipe discharge, head losses, and friction factor at hour number 3 for pipes (3- 16)

Network Table - Links at 3:00 Hrs

Link ID	Length m	Diameter mm	Roughness mm	Flow LPS	Unit Headloss m/km	Friction Factor
Pipe 3	193.45	300	0.0025	24.96	0.38	0.018
Pipe 4	36.39	300	0.0025	17.13	0.19	0.019
Pipe 5	60.75	300	0.0025	17.13	0.19	0.019
Pipe 6	65.42	300	0.0025	17.13	0.19	0.019
Pipe 7	34.59	300	0.0025	17.13	0.19	0.019
Pipe 8	189.35	300	0.0025	17.13	0.19	0.019
Pipe 9	82.00	300	0.0025	17.13	0.19	0.019
Pipe 10	93.23	300	0.0025	11.66	0.10	0.021
Pipe 11	73.72	300	0.0025	11.66	0.10	0.021
Pipe 12	164.01	300	0.0025	11.66	0.10	0.021
Pipe 14	36.57	300	0.0025	8.29	0.05	0.023
Pipe 15	88.54	300	0.0025	8.29	0.05	0.023
Pipe 16	123.39	300	0.0025	8.29	0.05	0.023

Figure (9) the pressure distribution for node number (203 as an example) was tracked and concluded that the pressure from hour number1 to hour number9 is low because the network works by gravity in this time duration. Then the pressure is getting high after turning on the pump and turn off the bypass pipe at the same time. Figure (10) shows the head for the tank which is from 177m to 162 m(from the top to bottom of the tank).

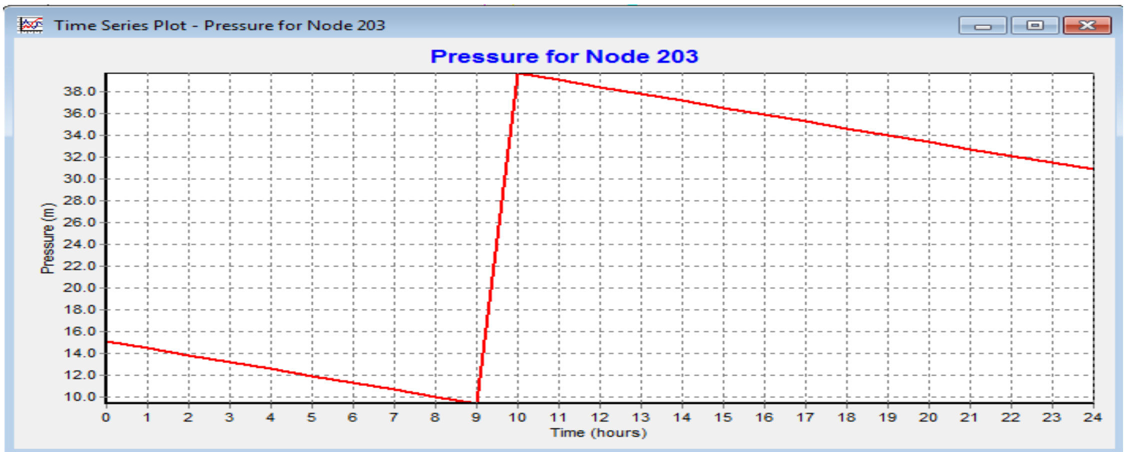

Figure (9).Time series pressure for node number 203

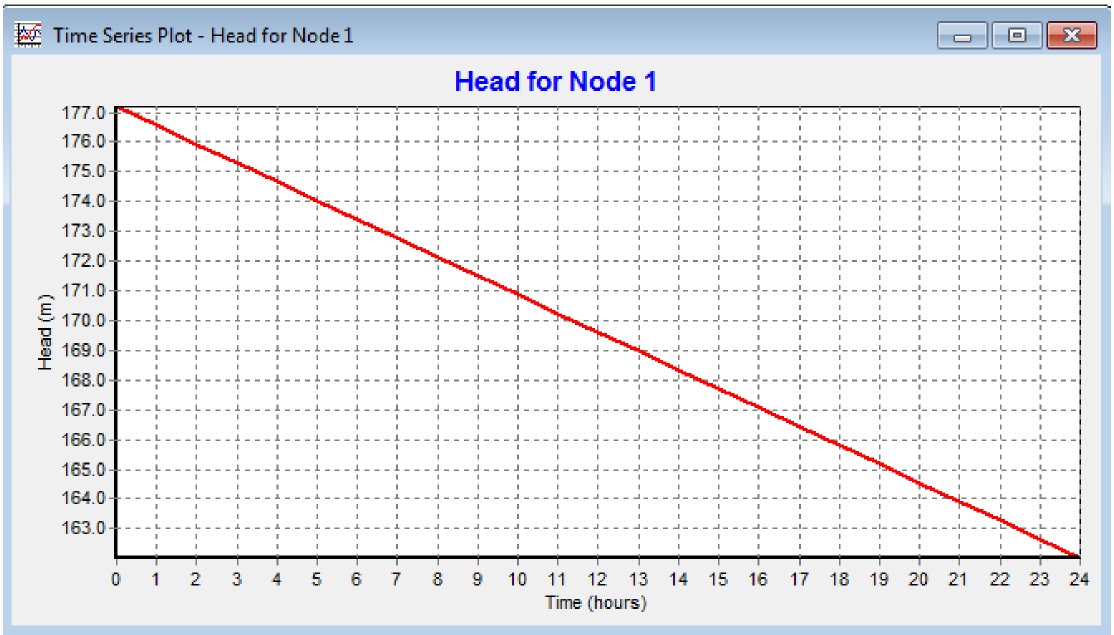

Figure (10). Tank time series for the tank head

4.2 The optimization results

As shown in figure (11), the pump and bypass pipe system are connected so that the pipe is on for the first ninth hours and the pump is on for the rest of fifteenth hours as shown in table (6) which illustrates the pump time series as a function of the flow, the head losses, and the pump status.

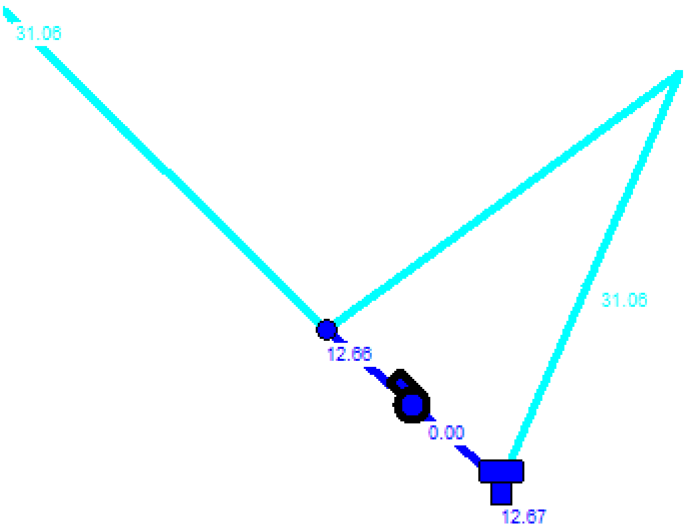

Figure (11) adding pump with bypass pipe

Table (6). Pump time series with (flow, head loss, status

Time Series Table - Link 1

Time Hours	Flow LPS	Unit Headloss m/km	Status
0:00	0.00	0.00	Closed
1:00	0.00	0.00	Closed
2:00	0.00	0.00	Closed
3:00	0.00	0.00	Closed
4:00	0.00	0.00	Closed
5:00	0.00	0.00	Closed
6:00	0.00	0.00	Closed
7:00	0.00	0.00	Closed
8:00	0.00	0.00	Closed
9:00	0.00	0.00	Closed
10:00	31.06	-30.96	Open
11:00	31.06	-30.96	Open
12:00	31.06	-30.96	Open
13:00	31.06	-30.96	Open
14:00	31.06	-30.96	Open
15:00	31.06	-30.96	Open
16:00	31.06	-30.96	Open
17:00	31.06	-30.96	Open
18:00	31.06	-30.96	Open
19:00	31.06	-30.96	Open
20:00	31.06	-30.96	Open
21:00	31.06	-30.96	Open
22:00	31.06	-30.96	Open
23:00	31.06	-30.96	Open
24:00	31.06	-30.96	Open

After adding the pump the positive pressures is clearly seen as shown in table (7) compared to the same result before adding the pump that can be seen in table (2).

Table (7). Positive pressure after inserting pump

Network Table - Nodes at 11:00 ...

Node ID	Pressure m
Junc 8	40.66
Junc 9	41.58
Junc 10	41.58
Junc 11	42.57
Junc 12	42.55
Junc 13	43.55
Junc 14	50.51
Junc 15	52.49
Junc 16	54.49
Junc 17	54.48
Junc 18	59.46
Junc 19	61.46
Junc 20	62.46
Junc 21	62.45
Junc 22	64.45
Junc 23	66.44
Junc 24	67.44
Junc 25	68.44

The next two tables show the cost of electricity once the pump is operated for the whole day which was 21.54 $/day and the cost of electricity once the network operates partly by gravity and partly by pump which decreased to 12.57 $/day.

Table (8) electricity cost for full time pump (cost/ day)

Energy Report

Table Chart

Pump	Percent Utilization	Average Efficiency	Kw-hr /m3	Average Kwatts	Peak Kwatts	Cost /day
1	100.00	75.00	0.11	12.82	12.82	21.54
Total Cost						21.54

Table (9) electricity cost for part time pump (cost/ day)

Energy Report

Table | Chart

Pump	Percent Utilization	Average Efficiency	Kw-hr /m3	Average Kwatts	Peak Kwatts	Cost /day
1	58.33	75.00	0.11	12.82	12.82	12.57
Total Cost						12.57

Conclusion

EPANET software can run the network at any time series which help the user to investigate and analysis the solution step by step. The analysis solution time series steps help us to watch at which hour the pump need to be inserted to the network so that the network can be worked at the first part by gravity because the level of water in the tank still high. Therefore, by the optimization of adding pump at hour number 10, the energy was saved during using gravity at this first part instead of using the pump all the day. Finally, the EPANET can have all type of results that need to be shown. It also has the control page that can be coded by the user to control the network. Another advantages of EPANET software is that the demand can be controlled to supply the water to zones regarding to their need of water demands which will decrease the losses in water during the day.

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