Risk Assessment of Pumping Main Using Surge 2000

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***Abstract*— Hydraulic transients can induce large pressure forces and rapid fluid accelerations in a pumping main. These disturbances cause pump and device failures, system fatigue and pipe ruptures or bursts and also induce water quality problems. Proper analysis of transient and risk factors of existing pipes helps in the formulation of low-cost, long-range nondestructive pipe condition assessment. In this study, risk assessment of pumping main is carried out using Surge 2000. Pumping main of Adat panchayat of Thrissur district in Kerala is selected for this study, as the possibility of transients exists in the area due to its undulating topography. Digital pipe model is created in ArcMap 10 by compiling data collected from GIS, available construction drawing, and report. It is then imported to Surge 2000 and modeled for steady and transient state analyses. Transient analyses of the system are carried out for the worst cases like pump trip/shut down by using Surge 2000, which is based on wave characteristic method. The pipe burst risk factors for maximum pressure; minimum pressure and transient force are also formulated. The control measures are suggested with the help of Surge 2000 and found that the risks of the system failures are mitigated by the application of control measures. This study helps to estimate the approximate number of the pipe which are out of service, and can easily formulate a pumping main maintenance plan in advance to avoid the occurrence of burst pipes.**

Keywords—Transient analysis; Pipe burst; Risk factors; Surge 2000; Control measures

I. INTRODUCTION

Pipe burst is one of the key issues that affect the urban water distribution systems, and can lead to the interruption of water supply, loss of lives, property damage, and also induce water quality problems. If the time of the pipe burst incidents can be anticipated beforehand, a pipe network maintenance plan can be formulated in advance to avoid the accidents. [4].Transient analysis of piping systems is often more important than the analysis of the steady state operating conditions that engineers normally use as the basis for system design. Engineers must carefully consider all potential dangers for their pipe designs and estimate and eliminate the weak spots. They should then embark upon a detailed transient analysis before making decisions to strengthen their systems and ensure safe, reliable operations built-in.

The best water supply system is the one that is designed with a vision for the future demand. Existing water systems have to be evaluated and redesigned with a future perspective that includes a rehabilitation or replacement of existing system components due to the age factor [1]. It is very important to design and evaluate a given water supply system using the design flow as generally determined by the above considerations so as to ensure the adequacy and reliability of the system. Nowadays, computer models and software programmes are capable of analysing water distribution network models for pressure and flow conditions resulting from diverse design and operating scenarios. They can help to reduce the overall cost of water supply projects.

Yang et al. [8] presented a method to assess the risk of transients occurring for gravity main water supply system.Wang et al. [4] presented a method to assess the level of risk for each pipe and node by colour coding with the help of Hammer software. This method was applied for the pumping main water supply scheme of a city in China. Today, the software like GIS (with versatile features like mapping, digitization etc.) and user friendly software programs for transient analysis are available. So, it is easy and efficient to assess the risk of the existing distribution networks, even in remote areas. In this study, the pipe burst risk assessment method based on the water hammer analysis is done with the help of GIS and Surge 2000 software for a pumping main. The pipe maintenance plan is also suggested in advance to avoid the occurrence of failure of pipes. Hence the objectives of the study can be stated as:

- To assess the pipe burst risk of pumping main using transient analysis with the help of Surge 2000 software.
- To suggest remedial measures for mitigating the risk.

II. LITERATURE REVIEW

As flow conditions inevitably change, pressure transient analysis is a fundamental part of water supply scheme design and a careful analysis may contribute significantly to the reduction of water losses from these systems. Computerized transient-flow models have been used with great success in the analysis of water-hammer events. The two methods which are generally used for hydraulic transient analysis of pipe networks are Method of characteristics and Wave characteristic method.

Both the MOC and WCM obtain solutions at small time intervals at all junctions and components. However, the MOC also requires solutions at all interior points for each time step. The WCM handles these effects by using the pressure wave characteristics. The waves propagate through pipes at sonic speed and are modified for the effects of friction by a single calculation for each pipe section.The MOC require a calculation at all nodes and all interior points at each time step. However, the WCM requires a calculation at each node and one calculation for each pipe at each time step.

Wood et al. [6] compared MOC and WCM with example networks.The first example network was studied earlier by Streeter and Wylie in 1967[3]. The network comprises nine pipes, five junctions, one reservoir, three closed loops, and one valve located at the downstream end of the system. The valve is closed to create the transient. Both solutions, in MOC and in WCM, were compared and found that that the results were virtually indistinguishable.

Wang et al. [4] derived the hydraulic calculating equations based on Method of Characteristics (MOC) by considering the pipe head loss and node cavitation. Four individual factors and one composite factor for hydraulic transient risk are presented along with the method of calculation for the indicators and a tabular result that was colour coded by risk. Burst risk factors include risk for maximum pressure, maximum vapour pressure, and maximum vacuum, maximum transient force. Computerized pipe network model was established with the help of GIS. Pipe burst risk assessment of network was done using HAMMER Software.

Yang et al. [8] established a computer model of water supply system under gravity with a total length of 71km, 127 air valves, 73 control valves, and one reservoir. They verified the model manually by checking the physical properties of the pipe network with inspecting profiles, charts and tables. They also built the water hammer analysis scenarios through adjusting the control valves on the aqueducts at the outlets. Then, they evaluated the pipe burst risk by scenario analysis and set a surge tank at the point of maximum vapour volume to prevent water hammer. In both cases of distribution systems, pumping main and gravity main, water hammer or transient is an important cause of the pipe burst and it is important to find its risk assessment by proper transient analysis.

III. METHODOLOGY

A. Modelling of Pumping main

It includes the development of digital pipe model in Arc Map 10 and development of digital model of pumping main for the analyses in Surge 2000.

The pipe in digital form is necessary for the software aided analysis. The scaled map drawing can be converted in to raster data for Arc map 10 by scanning. Geo referencing and projection of the maps make it convenient to develop the digital model of pipe layout with actual length. Digitization by creating different shape files on the geo referenced maps for various pipes, gives the digital form of pipes.

Pumping main digital model in Surge 2000 consists of pipes, nodes, reservoir, valves and pumps etc. The importing of digital pipe model from Arc Map 10 to Surge 2000 is possible and various supported elements and devices mentioned can be updated to the model in the Surge 2000 for the analysis purposes.

B. Analysing the pipe network model at steady state condition using Surge 2000 software

The static analysis of the network is to be done to find out the heads of each pipe and node. The important things considered while doing steady state analysis of a pumping main are the calculation of head loss of pipe, reservoir water level, sump level and design flow of pump.

Darcy –Weisbach equation is selected as head loss formula for the steady state analysis.

Head loss can be calculated with the following formula.

$$h_f = \frac{fLV^2}{2gD} \tag{1}$$

where h_f is the head loss due to friction (SI units: m); L is the length of the pipe (m);D is the hydraulic diameter of the pipe (for a pipe of circular section, this equals the internal diameter of the pipe) (m);V is the average velocity of the fluid flow, equal to the volumetric flow rate per unit cross-sectional wetted area (m/s);g is the local acceleration due to gravity (m/s^2);f is a dimensionless coefficient called the Darcy friction factor.

C. Analysing the Pumping Main Model at Transient State Condition Using Surge 2000 Software

Water hammer occurs whenever the fluid velocity in pipe systems suddenly changes, such as at pump stop, and pump start up or during valve opening and closure. These scenarios are to be designed for the simulation of transients. The transient analyses based on these scenarios are to be carried out.

Transient analysis of Surge 2000 program is based on wave characteristics method. This procedure initially developed as the “wave plan method” (Wood et al. [7]) yields solutions which are virtually identical to those obtained from exact solutions or those based on the method of characteristics. This method is based on the physically accurate concept that the transient pipe flow results from the generation and propagation of pressure waves that occur as a result of a disturbance in the pipe system like valve closure pump trip, etc. A pressure wave, which represents a rapid pressure and associated flow change, travels at sonic velocity for the liquid-pipe medium, and the wave is partially transmitted and reflected at all discontinuities in the pipe system like pipe junctions, pumps, open or closed ends, surge tanks, etc. A pressure wave can also be modified by pipe wall resistance. This description is one that closely represents the actual mechanism of transient pipe flow. [5]

D. Formulation of Pipe Burst Risk Factors.

There are three major risks due to transients. That is because of maximum pressure, minimum pressure and transient force.

1) Risk factor for maximum pressure of each node: Pipe burst risk due to of water pressure depends on two aspects, namely, the maximum water pressure and the designed safety pressure of each pipe. Depending on the pipe materials, the pipe wall thickness, and the production process, the designed safety pressure of the pipe is not fixed. The pipe burst risk due to maximum pressure is calculated as the following formula. [4]

$$P_{max} = \text{Max}\,(P1\ldots..Pi), \tag{2}$$

from 1^{st} to i^{th} transient simulation scenario
Where, P_{max}=Maximum pressure

Risk due to maximum pressure,

$$R_1 = \frac{(P_{\max} - P_b)}{P_b}, \tag{3}$$

When $R_1<0$, $R_1=0$
Pb= designed safety pressure

2) Risk factor of minimum pressure: If P_{min} is the minimum calculated pressure among the scenarios,

$$P_{min} = \text{Min}\,(P1...Pi), \tag{4}$$

from 1^{st} to i^{th} transient simulation scenario
R_2 is the Risk due to minimum pressure

$$R_2 = \frac{P_{\min}}{P_v}, \tag{5}$$

When $R_2<0$, $R_2=0$
P_v = maximum vacuum or vapour pressure (generally -1 bar).

3) Risk factor of maximum transient force of each node: If F_{max} is the maximum transient force among the scenarios,

$$F_{max} = \text{Max}\,(F1\ldots.Fi) \tag{6}$$

$$F_{max} = P_{max} * \text{inner cross sectional area of pipe} \tag{7}$$

R_3 is the risk factor due to transient force,

$$R_3 = \left(\frac{F_{\max} - F_b}{F_b}\right), \tag{8}$$

When $R_3<0$, $R_3=0$
Where, F_b=Impact force,

F_b=1.25*maximum calculated impact force of steady state

$$F_b = 1.25 * P_{\text{steady state}} * \text{inner cross sectional area of pipe.} \tag{9}$$

Where, $P_{\text{steady state}}$ = Pressure at steady state.

4) Maximum pipe burst risk factor of a node: The maximum risk of the node can be determined as,

$$\text{Maximum pipe burst risk factor, } R = \max\,(R_1, R_2, R_3) \tag{10}$$

E. Recommending Remedial Measures for High Risk Pipes and Nodes.
If transients cannot be prevented, specific devices to control transients are needed. In Surge 2000, various provisions are available for surge control.

IV. STUDY AREA

The Adat Gramma Panchayat is located about 6 km north-west of Thrissur Corporation and surrounded by Kolazhy, Kaiparamb and Tholur Panchayaths. The Panchayath is located near the suburban belt of Thrissur Corporation. The topography of the study area, the Adat Gramma Panchayat of Thrissur is an undulating type. The supply scheme includes a pumping main from sump at Puzhakkal to tank at Vilangankunnu and gravity main from tank at Vilangankunnu.

The pumping system consists of a sump of 42000litres capacity at Puzhakkal, 250mmAC pumping main and a GL tank at Vilangankunnu. The sump is a rectangular underground water tank. The overall internal size of the tank is 5 X 3 X 3.6.The available depth of storage is 2.8m. The bed level of the tank and level of the foot valve are taken as +0.85m and 1.35m respectively. The GL tank at Vilangan of 3 lakh capacity is fed by pumping from Puzhakkal pump house. Its bed level is fixed at +85m and delivery level is fixed at 87.85m. The water from Peechi Treatment plant is collected in the sump and the water is pumped to this tank. The available depth of storage is 2.85m.The pumping main is of the length 1765m in length. There are no air valves in the system .The pump is a 50HP 1440rpm centrifugal multistage pump with rated head of 91m.The efficiency of the system is taken as 60%.

V. DATA ANALYSIS, RESULTS AND DISCUSSIONS

A. Modelling of Pipe Network

The various processes involved in the modelling of pipe network were as follows.

1) Development of digital pipe network in ArcMap 10 by compiling the data collected from GIS, construction drawings and report.

2) Development of digital model of pipe network using Surge 2000.

The obtained construction drawing includes the layout of pipes with different colours corresponding to their respective diameters, surveyed points and its elevations, roads and place marks. The map was in scale and hence, the lengths of pipes were obtained directly from the map. In order to convert this layout in digital form, ArcMap10 was used. Initially, the pipe layout map was scanned and converted in to raster data for ArcMap10.

In order to locate Adat Panchayat, Google earth was opened. Adat network folder was created. Road junctions and locations were identified and all were stored as kml files. Then Arcmap10 was opened and from the conversion tool, the kml files were converted into layer files.

Then, these layer files were converted into point shape files. Merge tool in geo processing was used to merge all these point shape files to one shape file and it was then projected to UTM WGS 1984, 43N. The geo referencing was done by picking the place marks as points in the merged point shape file and the similar points in the scanned map. RMS error was found zero and hence, geo referenced map was projected in to UTM coordinates (WGS 1984, 43N). The accuracy was checked by bringing map back to google earth and it was found in position.The registered maps were added to Arc Map 10. Then, to get a digital model of pipe network, digitalization of pipes were done by creating shape files of polylines on the corresponding pipes in the geo referenced map. As the scanned maps were geo referenced and projected to UTM (WGS 1984, 43N), the surveyed elevations shown in the map were verified with the projected SRTM DEM. It was found satisfactory. The length of pumping main obtained from the digital model and from the design report of Adat water supply scheme is found to be 1765m. Thus, the network model development of pumping main was verified.

The digital model of layout in Arc Map 10 was imported to Surge 2000 for the analysis. The model was completed after updating the information about pipes, nodes, reservoir, sump, pump and valves. The input data for pipes were pipe material, pipe diameter, thickness and wave speed. The wave speed was calculated from the tool 'wave speed calculator, in Surge 2000 by providing pipe material and thickness as inputs. Table 1 shows pipe input data.

TABLE1. PIPE INPUT DATA

Nominal diameter (mm)	Thickness (mm)	Wave speed (m/s)	Working Pressure(kg/cm2)	Material
250	11.735	933.3	10	Asbestos Cement

The reservoir level and its elevation were the input parameters for the execution of software. Sump at Puzhakkal was also given as a reservoir with its water surface level and bottom elevation as input parameters. The available depth of storage is 2.85m. Pump was modelled as constant flow type for steady state analysis. The design flow in the pump is 24l/s which are taken from the design report of supply scheme. Selecting the option 'Pump file' as 'constant flow' is not suitable for transient flow modelling. The File type option is used in Surge 2000 which is considered for the transient analysis. From the 'Tools', in Surge 2000 pump file/calculate inertia' was selected and input parameters were given to calculate the inertia.

The inertia obtained for the pump was 8.17Nm^2.The pump data obtained from the software and the available Adat water supply scheme report is shown in the Table 2.

TABLE 2 PUMP INPUT DATA

Pump speed	1450rpm
Pump efficiency	60%
Flow rate	0.024m^3/s
Pump head	86.36m
Pump inertia	8.17

B. Steady State Analysis of Pumping Main

Pumping main consists of 250mm AC pipe having length of 1765m.The design flow specified for the pumping main was 24l/s and the pump option 'constant flow' was taken for the analysis to maintain the design discharge in the pipe. The analysis was done by selecting the Darcy Weisbach head loss formula option provided in the Surge 2000 software. The profile showing the results of pumping main is shown in Fig. 1 Table 3 shows the results given by the software, verified by checking it with that obtained manually using Darcy Weisbach Formula.

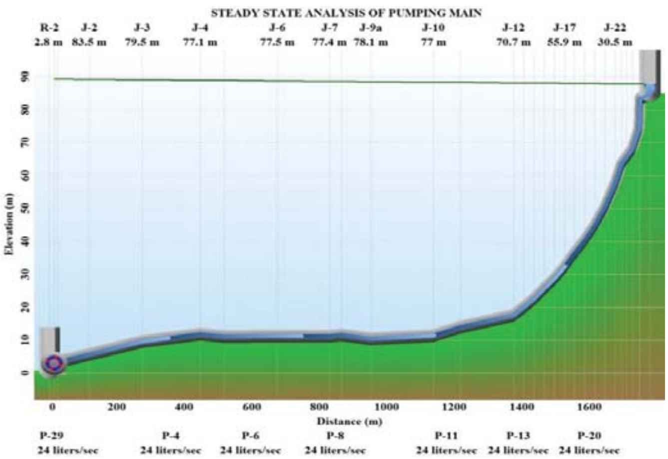

Fig.1 Steady State Analysis of Pumping Main

TABLE 3. STEADY STATE RESULTS OF PUMPING MAIN IN SURGE 2000

Node Name	Hydraulic Grade (M)	Node Elevation (M)	Pressure Head (M)
J-1	89.35	3.54	85.81
J-2	89.27	5.77	83.5
J-3	89.14	9.64	79.49
J-4	88.99	11.94	77.05
J-5	88.93	11.23	77.7
J-6	88.79	11.32	77.47
J-7	88.66	11.26	77.4
J-8	88.63	11.61	77.02
J-9a	88.56	10.47	78.09
J-11	88.33	13.99	74.34
J-12	88.2	17.54	70.66
J-13	88.17	19.94	68.23
J-14	88.14	22.47	65.68
J-15	88.12	25.6	62.51
J-16	88.09	28.6	59.49
J-17	88.07	32.18	55.89
J-18	88.04	36.26	51.78
J-19	88.02	40.14	47.88
J-20	87.99	44.64	43.35
J-21	**87.96**	**50.2**	**37.76**
J-22	**87.94**	**57.45**	**30.48**
J-23	**87.92**	**63.47**	**24.46**
J-24	**87.91**	**65.5**	**22.41**
J-25	**87.9**	**67.9**	**19.99**
J-26	**87.88**	**74.04**	**13.84**
J-27	**87.88**	**83.27**	**4.6**
I-Pump-	**3.64**	**3**	**0.64**
R-1	**87.85**	**85**	**2.85**
R-2	**3.65**	**0.85**	**2.8**
O-pump	**89.36**	**3**	86.36

C. Transient Analysis of Pumping Main

A pump can stop due to power failure, pump failure or planned pump stop, and will create transient flow in the system. The transient analysis was carried out for the scenarios like pump trip, pump shutdown and pump start up. From these, the worst scenarios selected for the transient analysis were pump shut down and pump trip. Pump is a centrifugal pump with a check valve. Various cases opted for the surge analyses are

- Case 1: Pump trip at 0.01sec with a check valve closure at 0.5sec. It was the worst case scenario among 4. It is shown in Fig.2.
- Case 2: Pump trip at 0.01sec with check valve closure at 0.1sec
- Case 3: Pump trip at 0.01sec with check valve closure at 0sec
- Case 4: Pump shutdown at 2sec with check valve closure at 0.5sec. The option for shutdown in the 'Change' table was selected. The reasonable time 2sec was set for shutdown.

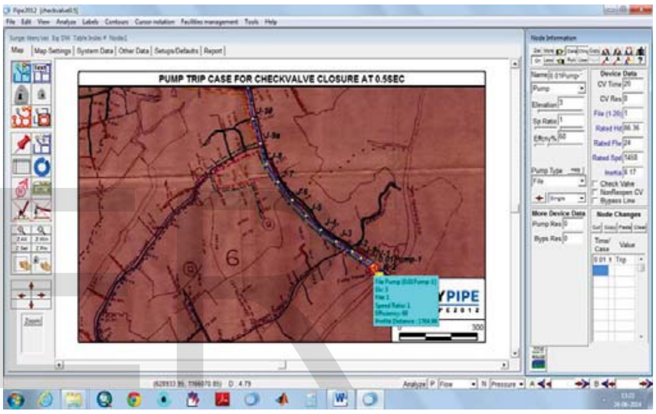

Fig.2 Transient modelling by Pump trip at 0.01sec

The maximum pressure experienced by the nodes of pumping main in each case is shown in Fig.3

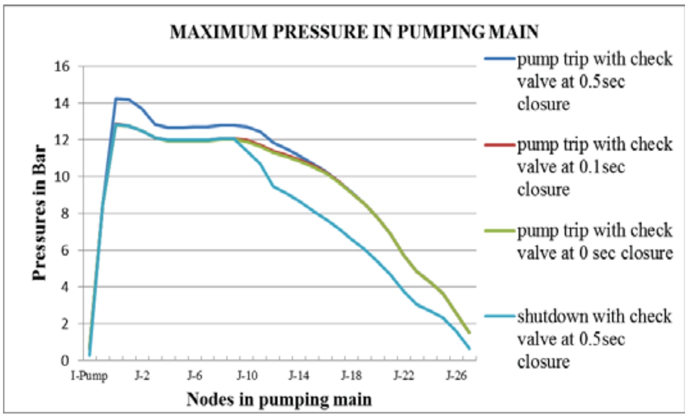

Fig.3 Maximum pressure at nodes by the simulated scenarios in pumping main

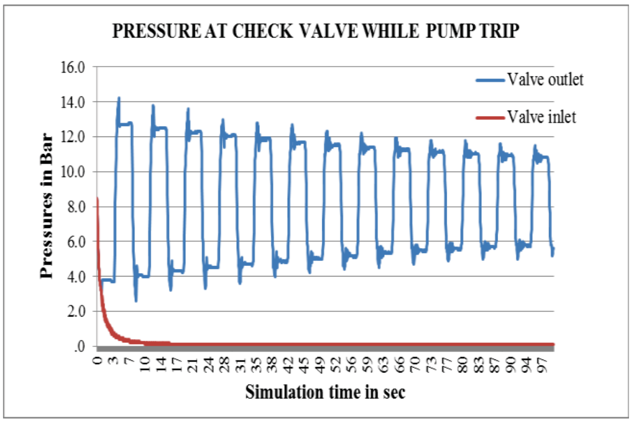

Fig.4 The Pressure at check valve while pump trip

From the results, the maximum pressure was at the node near to check valve and it was 14.26bar. The test pressure of 250mmAC pipe is 14.7bar (15kg/cm^2) as per IS 6530:1972. The working stress is 9.8bar. Hence, there is a risk of burst in the system

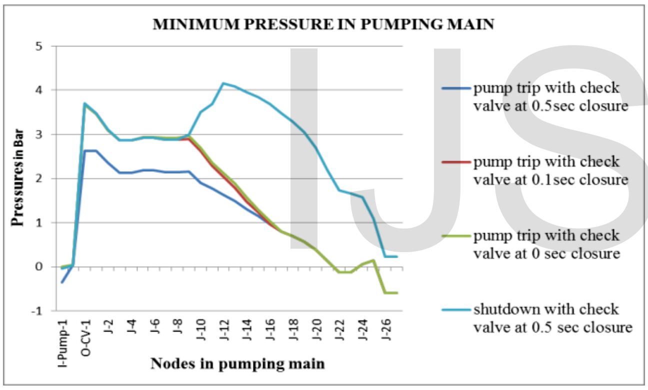

Fig.5 Minimum pressure at nodes in the simulated scenarios in pumping main

Fig. 5 shows the minimum pressures experienced by the nodes of pumping main. The minimum pressure -0.6bar was found at J26 and J27 nodes which are the higher elevation nodes in the rising main. The chance for negative pressure is higher at higher elevation and this fact justifies the obtained result given by the software. Fig.6 shows the pressure envelope of pumping main, which is obtained from the Surge 2000. Yellow colour portion of the profile represents the pressure within the design limits. High pressure area is represented by green colour. Pink colour represents the area of low pressure.

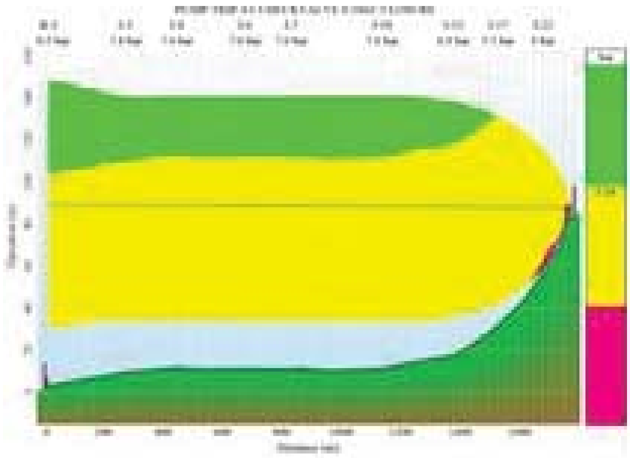
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Fig.6 Pressure Profile from Surge 2000 at Pump trip

D. Pipe Burst Risk Calculation

After getting the maximum and the minimum water pressure and the transient force of each node, the pipe burst risk to the pumping main was evaluated from the following aspects.

1)Risk factor due to maximum water pressure at each node: Pipe burst risk due to of water pressure depends on two aspects, namely, the maximum water pressure and the designed safety pressure of each pipe. The design safety pressure or working pressure for 250mm AC pipe is 9.8bar. The pipe burst risk due to high-pressure is calculated as per the Eqn.(2) and Eqn.(3)

2) *Risk factor of minimum pressure of each node:*

Pmin is the minimum calculated pressure in bar, among the scenarios .The corresponding risk was calculated using the Eqn. (4) and Eqn. (5)

3) Risk factor of maximum transient force of each node

F_{max} is the maximum calculated transient force among the scenarios. It was calculated by using the Eqn. (6) and Eqn. (7) and risk was calculated using the Eqn. (8)

4) Maximum risk factor

R is the maximum pipe burst risk factor of a node. It was obtained as per Eqn.(10).

5) Pipe Burst Risk Level Classification

Pipe burst risk is classified through the four-layer state assessment division mechanism. That is the safe level, warning level, the dangerous level and the severe level. [4].

The range of the composite risk and its level are specified below

0-0.25=> Safe Level
0.25-0.5=> Warning Level
0.5-0.75=> Dangerous Level
>0.75 => Severe Level.

Table 4 shows the calculation of maximum risk of each node and its level of risk.

TABLE 4. MAXIMUM RISK OF EACH NODE AND ITS LEVEL OF RISK.

Node	R_1	R_2	R_3	R	Level
J-1	0.45	0	0.35	0.45	Warning
J-2	0.40	0	0.34	0.40	Warning
J-3	0.31	0	0.32	0.32	Warning
J-4	0.29	0	0.34	0.34	Warning
J-5	0.29	0	0.33	0.33	Warning
J-6	0.29	0	0.34	0.34	Warning
J-7	0.29	0	0.34	0.34	Warning
J-8	0.30	0	0.34	0.34	Warning
J-9a	0.30	0	0.34	0.34	Warning
J-10	0.30	0	0.34	0.34	Warning
J-11	0.27	0	0.37	0.37	Warning
J-12	0.21	0	0.37	0.37	Warning
J-13	0.17	0	0.38	0.38	Warning
J-14	0.14	0	0.38	0.38	Warning
J-15	0.09	0	0.40	0.40	Warning
J-16	0.05	0	0.41	0.41	Warning
J-17	0	0	0.42	0.42	Warning
J-18	0	0	0.44	0.44	Warning
J-19	0	0	0.45	0.45	Warning
J-20	0	0	0.46	0.46	Dangerous
J-21	0	0	0.48	0.48	Dangerous
J-22	0	0.12	0.53	0.53	Dangerous
J-23	0	0.12	0.61	0.61	Dangerous
J-24	0	0	0.56	0.56	Dangerous
J-25	0	0	0.49	0.49	Dangerous
J-26	0	0.6	0.52	0.6	Dangerous
J-27	0	0.6	1.67	1.67	Severe
R-1	0	0.36	0	0.36	Warning
R2	0.45	0	0	0.45	Warning
O/ PUMP	0	0.1	0.35	0.35	Warning

Nodes from J20 to J27 are higher elevation nodes and having chance of negative pressure. Since there were no air valve or other hammer protection equipment installed in the system, it experience high risk due to the negative pressure during pump trip. The Table 4 shows that the dangerous nodes are mainly due to negative pressure and severe level is due to transient force experienced by the node.

E. Control Measures in Pumping Main

The main functions of control devices are to detect the severe trouble in the system and to take appropriate corrective action so that the pipeline pressures remain within the design limits. Trials were done with feasible control measures like air valves and pressure relief valves provided in the Surge 2000 to mitigate the risk. Putting air valves at all the high points in the pipeline was not a safe measure when simulating a pump trip. Pressure relief valve near high pressure nodes was not a feasible solution as it made problems in other nodes by creating negative pressures. Since the pipe line profile shows sharp elevation, the air vessel or closed surge tank was selected as a surge control measure for high pressures as well as for negative pressures. The position of air vessel was fixed near the pump downstream.

***1)** Size Required For the Surge Tank*

For getting the minimum size required of the closed surge tank, a thumb rule was used.To calculate the approximate time taken for a wave to travel down the pipeline and back, the average wave speed of pipe and the pipe length along which the wave travels are taken.

Here the pipe length, L=1765m

Total distance covered by wave, $S=2L$

=1765x2=3530

Wave speed through 250mm AC pipe, V=933m/s

Time for travel, T=3530/933=3.78sec

Design flow in pipe, Q=0.024m^3/s

Then Minimum size required for the surge tank

to accommodate the flow = $Q*T$

=0.024x3.78=0.09m^3

The tank starting with the dimension 0.09m^3 was applied in the model. But it could not mitigate the risk fully. So trials were done to accomplish the measure which can control all the pressures in the system. After a number of trials, a closed surge tank with a volume of 0.6m^3 was obtained as the optimum size for a safe system.

2) Closed Surge Tank and Its Dimensions

The closed surge tank dimensions obtained from the trial and error method are as follows.

Total volume=0.6m3

Air volume=0.3m3

Diameter=0.50m

Height=3m

3) Pipe Burst Risk Calculation after Control

Fig.7 shows the maximum and minimum pressure experienced by each node after control.

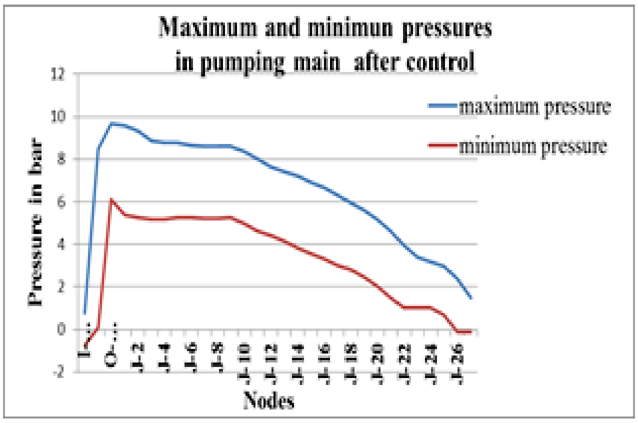

Fig.7 Maximum and minimum pressure experienced by each node after control

Table 5 shows the risk at the pumping nodes after the control

TABLE 5. RISK AFTER THE CONTROL

NODE	P max (bar)	P min (bar)	*R1*	*R2*	*R3*
J-1	9.59	5.4	0	0	0
J-2	9.31	5.27	0	0	0
J-3	8.85	5.16	0	0	0
J-4	8.79	5.16	0	0	0
J-5	8.79	5.27	0	0	0
J-6	8.64	5.27	0	0	0
J-7	8.62	5.23	0	0	0
J-8	8.6	5.23	0	0	0
J-9a	8.6	5.24	0	0	0
J-10	8.35	4.98	0	0	0
J-11	8.03	4.62	0	0	0
J-12	7.64	4.39	0	0	0
J-13	7.43	4.14	0	0	0
J-14	7.2	3.83	0	0	0
J-15	6.92	3.56	0	0	0
J-16	6.64	3.3	0	0	0
J-17	6.31	3.03	0	0	0
J-18	5.94	2.78	0	0	0
J-19	5.58	2.46	0	0	0
J-20	5.16	2.05	0	0	0
J-21	4.64	1.49	0	0	0
J-22	3.95	1.03	0	0	0
J-23	3.38	1.01	0	0	0
J-24	3.19	1	0	0	0
J-25	2.97	0.69	0	0	0
J-26	2.38	-0.13	0	0	0
J-27	1.47	-0.13	0	0	0
I-0.01Pump-	0.77	-0.75	0	0	0
O-CV-1	9.65	6.12	0	0	0
O-0.01Pump-	8.47	0.1	0	0	0

From the Table 5, it is clear that the system is safe after the control. Fig.8 shows the profile of pumping main with control. It can be seen that pressure of each node is with in the design limits.

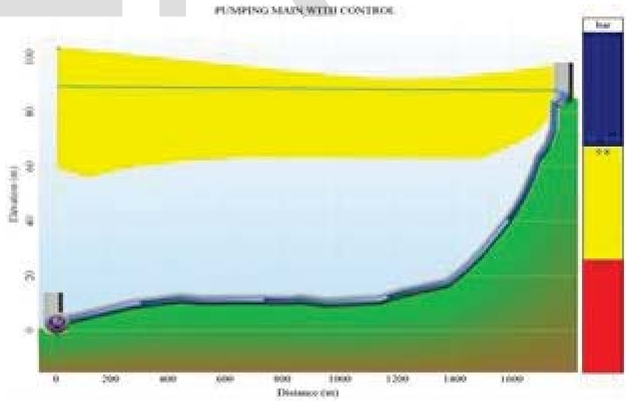

Fig.8 Pressure Profile at pump trip after control

VI. SUMMARY AND CONCLUSION

In this paper, Adat Gramma Panchayat situated in Thrissur district of Kerala was selected as the study area and the pipe burst risk assessment of pumping main was carried out by using Surge 2000.

A) Summary

Digital model of the Adat pumping main layout was developed and verified with the data of the design report of water supply scheme and SRTMDEM.Steady state analysis of pumping main was done by Surge 2000 and verified manually with Darcy Weisbach formula. Transient analyses of pumping main with simulated scenarios like pump start up, pump shutdown and pump trip were done. Based on hydraulic transient flow analysis, pipe burst risk factors for maximum water pressure, minimum pressure, maximum transient force and maximum risk were formulated.Risk factors of the pumping main with protection were calculated and found that the risk of the system is zero.

B) Conclusions

Based on the study, the following conclusions were made. ArcGIS 10.1 can be used for the digitization of pipe network. Steady state analysis and transient state analysis of complex networks can be done using Surge 2000.

In the transient analysis of pumping main, pump start up, pump shutdown and pump trip were the simulated scenarios. Pump trip was obtained as the worst case. The pipes in the rising portion of pumping main were in risk while pump trip. A closed surge tank located near the pump was found as the protection device in pumping main for mitigating the risk.

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