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Drinking Water Engineering and Science Discussions

Interactive comment on "Reliability of water distribution networks due to pumps failure: comparison of VSP and SSP application" *by* N. Mehzad et al.

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Responses of the authors to the reviewers' comments on the paper entitled "Reliability of water distribution networks due to pumps failure: comparison of VSP and SSP application" By N. Mehzad, M. Tabesh, S. S. Hashemi, and B. Ataee Kia

Referee #1 General comment The paper deals with the evaluation of the reliability of a water distribution system served by a pumping station and in particular with the increase of reliability deriving from the use of variable speed pumps compared with single speed pumps. The topic is of interest for the readership of Drinking Water Engineering and Science. The paper is clearly organized, but C1: in many points the English lan-

guage is poor, or even wrong in some cases, and I recommend that it is checked by a mother tongue. A1: First of all, many thanks for your helpful comments. We have tried to consider all the technical and language comments in the revised manuscript.

About the scientific contents of the manuscript, C2: the presented application seems just an exercise, and A2: In this paper, to calculate the reliability of water distribution networks, a new concept is proposed based on the reliability of pumping stations which is applied on the real WDN of Vardavard City in Iran. The optimization programming scripts are available and our new and developed methodology is stated in our paper. Therefore it can be stated that this paper is more than an exercise. Because of this, the other referees believe new contributions of this paper. C3: the validity of the main conclusion drawn by the authors in the revised manuscript (the use of VSP increases the reliability of the system, which is probably obvious regardless of this manuscript) is not supported by the presented results and their discussion: in particular. A3: The main conclusion is more discussed and also better stated. (Line 11, Page 361). C4: it is plain that the result strongly depends upon: (i) the shape of the relationship expressing the reliability at a single demand node; (ii) the probability of failure of the pumps. A4: The proposed reliability relationships are calculated at each node and then are computed for the entire network using weighted mean of nodal values. Therefore the proposed formulations are a general statement. On the other hand for the probability of failure of pumps please see our response for comment #20. C5: Both these quantities have been assigned without any explanation. In particular, for the first, C6: the three checked shapes seem arbitrary; for the second, C7: no information is provided about how the probabilities of failure have been evaluated (I have doubts about such values, as explained in the following "detailed comments" section). A5, A6, A7: In order to explain the comment about the assigned quantification and equations, I want to add the following statements: This paper is in continuation of the research which was conducted in 2011 and published in CCWI proceeding. In that research, the WDN was analyzed based on the first nodal pressure equation. In this paper, to reach the closest solution to the real condition of a WDN, the second nodal pressure equation is proposed to consider the maximum allowable nodal pressure. The difference between equation (1) and equation (2) is more visible in low daily consumption hours. In the next step, to promote the reliability calculation, the third nodal pressure equation, which is derived from Tabesh & Zia (2003), has been considered. The results of the three considered equations are compared. More information is provided in the comment #20 about the probability calculations.

C8: I also have some minor concern about the use of the word "fuzzy" for the relationships expressing the reliability at demand nodes: usually the recourse to fuzzy variables is done when the vagueness of truth is such that a certain degree of truth can be found even in opposite statements, and the membership functions are introduced just to quantify the degree of truth of opposite statements. In this case, I understand that the proposed relationships are just a way to quantify the degree of fulfillment of design requirements at nodes. In conclusion, I think that the manuscript cannot be accepted in its present form and that major revisions are needed. A8: According to your advice, fuzzy equation is changed to nodal pressure equation. In particular, C9: the choice of the expressions (1), (2) and (3) (especially the last two) must be discussed and motivated, A9: It is discussed in A5, A6, A7. C10: as well as the evaluation of the probabilities of pump failure. A10: More information is provided in comment #20.

Detailed comments C11: Pag. 355, lines 17-20: I suggest to discuss here the limitations of a Demand Driven approach rather than at pag. 358, lines 27-29; A11: This comment is applied in the new version. C12: Eq. (1) and pag. 356, line 3: clarify the meaning of the pressure head HMIN; A12: In the line 3, page 356, HMIN is explained.

C13: Pag. 356, line 12, Eq. (3) and fig. 2: what are H1, H2 and H3? If they are just shape parameters of the reliability expression, as I guess, their choice should be discussed; A13: In the line 12, page 356, these parameters are assigned to explain the better behavior of the curve.

C14: Pag. 356 and figures 1 and 2: the choice of the expressions of the reliability at

nodes (especially eq. (3)) should be discussed and clarified; A14: It is discussed in C5, C6, C7.

C15: Pag. 357, eq. (4) and lines 6-7: I really don't understand how the use of demands to weigh the reliability at nodes could "increase the accuracy of the reliability calculation" (it makes no sense); A15: In this paper, the equations are weighted, because the nodes with higher demand are more important and all of the nodes should not have the same degree of importance.

C16: Pag. 357, lines 14-15: the Authors should provide more information about the analyses carried out to evaluate rsc; A16: It is discussed in comment #20.

C17: Fig. 3 and pag. 358, lines 3-4: counting the nodes (they result 78, as stated two lines above), it seems that the entire network is depicted, and not only a part; A17: In line 1, page 358, it is stated that the figure and the information belongs to the south part of the system.

C18: Pag. 358, lines 11-12: it should be made clearer that the obtained result have not general validity, but refer only to the considered network; A18: In line 5, page 361, it is stated in C3 that for each special network, this can be different. However, in general, Variable Speed Pump (VSP), leads to a higher reliability of the system than using Single Speed Pump (SSP) based on the reliability calculation.

C19: Table 1 and pag. 358 lines 13-14: the table provides the pumping schedules, and not the "demand levels", as stated. However, it would be worth to add a table or a figure with the temporal demand pattern; A19: In the text, this comment is applied by changing "various demand levels" to "pumping schedules" and "pumping scheduling" to "pumping station".

C20: Pag. 359, lines 16-18: how the probabilities were evaluated? The assumed values seem questionable, because, if the probability of failure of a single pump is 0.85 (extremely high), it's difficult to understand how the probability of two failures is 0.1. If the events were stochastically independent, the probability of two failures (the pumps have the same characteristics, as stated at pag. 358, line 3) should be 0.85x0.85=0.72. If the failure of pumps can be caused, at least in some cases, by the same reasons, the probability of contemporary failure is even higher than the product of the probabilities of single failures. This point is crucial for the entire study, because the obtained results strongly depend on the values assumed for ri. Thus, the Authors should thoroughly discuss it; A20: Many thanks for your comments. According to your comments, the probabilities of different scenarios are reconsidered. The failure probability of one pump is considered less than 0.85 and equal to 0.1. Accordingly, the failure probability of two, three, and four pumps are equal to 0.1*0.1=0.01, 0.1*0.1*0.1=0.001, and 0.1*0.1*0.1*0.1=0.0001 consequently. Figures and tables are revised. It is important to mention that despite these changes, the conclusion stayed the same and intact. Due to the unavailability of the data over the pumps' failure, the probability of pumps' failure is with fictive values and based on the suggestion of the experts. The next step of this research will be related to obtain the realistic probability for pump failures which will be reported in our next papers.

C21: Pag. 360, lines 16-19: equations (1), (2) and (3) should be discussed in a less simplistic way; A21: This comment is applied in the new version and discussed in detail.

C22: Pag. 361, lines 5-11: these conclusions strongly depend on the chosen equations expressing the reliability at single demand nodes. This point should be discussed before drawing conclusions; A22: It is discussed in page 361, line 5 before drawing conclusions.

C23: Pag. 361, lines 12-17: the use of pumps at speeds higher than the normal has not been investigated here; however, the conclusion is rather obvious. A23: The use of pumps with speed higher than the normal is proposed as a practical solution which should be investigated in further research.

Typing mistakes and English language errors I cannot assure that the following list is complete, so I repeat my recommendation to carefully check the English language, possibly with the help of a mother tongue. C24: Pag. 352, lines 18-20: check English language; A24: Pag. 352, lines 18-20: is checked and deleted.

C25: Pag. 353, line 10: replace "deference" with "difference"; A25: Pag. 353, line 10: is replaced.

C26: Pag. 353, lines 19-20: check English language; A26: Pag. 353, lines 19-20: is checked and changed to: "The study reveals that using VSP instead of SSP was effective in reducing the energy costs of Vardavard's WDN up to 5.43 percent."

C27: Pag. 353, lines 26-28: check English language; A27: Pag. 353, lines 25-28: is checked and changed to: "Because many different parameters are highly correlated in WDNs, reliability analysis of WDNs is very complicated. "

C28: Pag. 354, lines 11-14: check English language; A28: Pag. 354, lines 11-14: is checked and revised; "On the other hand, inability of a system in providing the demanded water discharge with acceptable defined pressure is a hydraulic failure. The mechanical failures or increase in water demand are the source of this type of WDN's failure (Tabesh, 1998)."

C29: Pag. 354, line 17: replace "Tanyiemboh" with "Tanyimboh"; A29: Pag. 354, line 17: is replaced.

C30: Pag. 354, line 19: replace "Goupta" with "Gupta"; A30: Pag. 354, line 19: is replaced.

C31: Pag. 355, lines 9-12: check English language; A31: Pag. 355, lines 9-12: is checked and changed to: "In this research, reliability of pumping stations in WDNs is calculated through linking the optimization model in Visual Basic by simulation in EPANET2.0. In the simulation, the failure scenarios of pumps in pumping stations are considered."

C32: Pag. 355, line 14: eliminate “in this research”; A32: Pag. 355, line 14: is deleted.

C33: Pag. 357, line 11: eliminate “of” between “scenario” and “sc”; A33: Pag. 357, line 11: is deleted.

C34: Pag. 358, line 3: the word “downer” should be replaced with “low”; A34: Pag. 358, line 3: the word “downer” is replaced with “low”;

C35: Pag. 359, lines 9-12: check English language; A35: Pag. 359, lines 9-12: is checked and revised to: “If mechanical failure occurs in the system and the pumps in pumping stations are failed accordingly, spare pumps are working and satisfy the nodal demand. However, the nodal pressures lower than the minimum allowable pressure in WDN may occur more probably."

C36: Pag. 360, line 23: check English language; A36: Pag. 360, line 23: is checked and changed to: “In this research, reliability calculation of pumping stations in a water distribution network is analyzed.”

C37: Pag. 361, lines 1-5: check English language; A37: Pag. 361, lines 1-5: is checked and revised: “According to the obtained results of this research, it can be concluded that if demand increases during the peak demand time of a day, the capacity of the network in providing the required water with specific pressure decreases, especially while the system experiences the mechanical failures. Moreover, if the number of mechanically failed pumps in pumping stations of a WDN increases, the amount of supplied water by pumps decreases. Therefore, it leads to a less reliable water distribution network.”

C38: Pag. 361, line 21: eliminate the word “tanks” between “system” and “by”; A38: Pag. 361, line 21: is deleted âĂČ Referee #2 This paper demonstrated the technical analysis and comparison of Reliability of WaterDistribution Networks Due to Pumps Failure; contribute to the theme of this journal.It can provide the reference point for other researchers. C39: Please check equations and type errors. A39: Many thanks

for your comments. Typing errors have been corrected in a new version. âĂČ Referee #3 General comments This paper presents a methodology to evaluate the reliability of pumping stations and this topic is of interest for the Drinking Water Engineering and Science readers.The text is well organized but C40: it should be reviewed by someone whose mother thong is the English. The reliability is here evaluated by using a sort of performance index, which authors call “fuzzy relationships”, that indirectly measures the amount of demand that can be fulfilled (in terms of available pressure at each node) in different failure scenarios, and each scenario corresponds to a pump(s) failure. A40: Many thanks for your comments. Based on your advice, the paper has been reviewed by an English speaker and English errors are corrected in the new version.

C41: Authors present three different equations to evaluate this reliability (although there is no justification for this choice): Eqs. (1) and (2) are “original” and Eq. (3) was taken from Tabesh and Zia (2003). A41: In order to explain the comment about the assigned quantification and equations, I want to add the following statements: This paper is in continuation of the research which was conducted in 2011 and published in CCWI proceeding. In that research, the WDN was analyzed based on the first nodal pressure equation. In this paper, to reach the closest solution to the real condition of a WDN, the second nodal pressure equation is proposed to consider the maximum allowable nodal pressure. The difference between equation (1) and equation (2) is more visible in low daily consumption hours. In the next step, to promote the reliability calculation, the third nodal pressure equation, which is derived from Tabesh & Zia (2003), has been considered. The results of the three considered equations are compared. C42: In my opinion, the use of Eq. (1) could/should be omitted. As authors mention, it doesn’t take into account the maximum pressure allowed in the network and it assigns maximum reliability to any pressure above the desirable pressure. This index doesn’t make sense. A42: This comment is true to some extent. However, equation 1 is stated in this paper as a mean to be compared with other equations. It reveals that considering the maximum allowable nodal pressure has a significant role in calculating the network’s parameters. C43: Eq. (2) is a simplistic way to envisage the performance of water distribution networks. But it makes some sense. A43: By considering the maximum allowable nodal pressure and accordingly, decrease the reliability of the system in equation #2, equation #1 is elevated to reach the closest solution to the real condition of a WDN. C44: I think that Eq. (3) is from far the best as it is more close to the performance that a water distribution network should present. The final value for the reliability takes in consideration the probabilities assigned to each failure scenario. A44: To promote the reliability calculation and more compliance with the real condition of a network, the third nodal pressure equation, which is derived from Tabesh & Zia (2003) has been considered. C45: However, authors don't mention anything about the values adopted for these probabilities. Although the presented methodology is interesting, A45: It is discussed in C20. C46: it would be much more realistic to use a Pressure Driven Demand model and evaluate directly the amount of demand that can be fulfilled and evaluate the reliability with it. After reading the text I got the idea that the proposed methodology assumes that the network is fed by one single pumping station, which may contain several pumps. A46: Using the available demand driven software of EPANET was the first step of this research. In the next phase, we aim to investigate the reliability by means of the hydraulic analysis of a WDN based on pressure (HDSM), which lacks in this research.

C47: I wonder if the authors thought how they would apply it to networks fed by more than one pumping station. A47: This concept can be applied on WDNs with several pumping stations. As an illustration, if there are two pumping stations (each with 3 parallel pumps), three scenarios are possible as follows. 1. Zero pump failure: all of the pumps in the two pumping stations are working well and reliability of the network is calculated according to this study. 2. One pump failure: one pump is failed in one of the pumping stations. If pumps in both of the pumping station have identical characteristics, this scenario may occur in both of the pumping stations with the same probability. In the hydraulic analysis, failure of one pump is considered in both of the pumping stations consequently and nodal pressures are calculated. The probability of failure in pumping stations is different if pumps' characteristics are different. 3. Two pumps failure: two

pumps are failed in one of the pumping stations or one pump in the first pumping station and one pump in the second pumping station fail. If pumps' characteristics differ in the pumping stations, the probability of failure should be calculated differently in the hydraulic analysis. All the possible scenarios are analyzed hydraulically and the nodal pressures are calculated. It is noteworthy that by increasing the number of pumps and pumping stations, the number of hydraulic analyses and complexity of the calculations are increased, especially if the characteristics of pumps and the pumping stations are not identical.

Specific comments C48: Some references have wrong names, like: "Tanyiemboh" and "Goupta". A48: It is revised in the new version.

C49: In Eq. (1) if HMIN is different from 0, when HAV=HMIN Coef is not 0. Is really this the authors intention? A49: In this research, because a hydraulic analysis is conducted; therefore, in some cases, not only the nodal pressure lower than minimum allowable pressure is possible, but also the negative pressure may occur. In the reliability calculation, when this situation happens, the system is not reliable anymore and the reliability of the system is zero. C50: Authors should be careful with the term "minimum absolute standard pressure", it may introduce some confusion between absolute and relative pressures. A50:As it is stated, absolute minimum pressure is used in the analysis of Networks.

C51: In Eq. (5) shouldn't NP be equal to the number of different failure scenarios considered (it may be different from the number of pumps)? A51: The various scenarios, from 0 pump failure to NP-1 pumps failure, are investigated. Therefore, NP scenarios are the failure modes and the number of scenarios is equal to the number of pumps. However, due to the fact that the number of pumping stations and the characteristics of the pumps may differ, this comment seems very interesting and in the new version it is applied. C52: In the case study, the operating points of the pumping station seems somehow strange: with two pumps in parallel the discharge doubles (the system curve is flat in this range – 0.0 to 1.4?); introduction of the third or the fourth pump gives the same increase in the discharge (once again the system curve is flat in that range – 1.4 to 2.4?). But if we look at Figure 4, it seems that the operating points are: 1 pump – 0.7; 2 pumps – 1.3; 3 pumps – 1.9; 4 pumps – 2.3, and these seem to be more realistic. A52: 1.4 is changed to 1.3 in the text.

C53: If there is no tank in the network, how is it fed? In Figure 3 we can see a reservoir. What is the physical meaning of this reservoir? The network feeding point has a constant head? A53: In this WDN, the pumping station pumps the water directly from the refinery to the system and there is no lost in the head. In the figure, reservoir is considered although in reality this is not the case. In general, in a perfect design, considering a tank is an important requirement which was not the case for this WDN.

C54: “In Table 2, the calculated negative reliabilities were replaced by 0.” Looking at Eqs. (1), (2) and (3) I don’t see how there can be negative reliabilities. Could the authors please explain this? A54: Yes, your comment is absolutely correct and it shouldn’t be negative. In the primary versions, because negative pressure restriction was not existed, negative reliabilities could be produced. In the final version, it is revised and this statement is deleted.

C55: “: : :the costs of the electricity consumption are 694.78 $ kw-1 and 597.75 $ kw-1 : : :”. What is the meaning of “$ kw-1”? If we are talking about costs shouldn’t it be just “$”? A55: The costs are in “Irainan Rial” which is revised in the new version.

Please also note the supplement to this comment:
http://www.drink-water-eng-sci-discuss.net/5/C239/2012/dwesd-5-C239-2012-supplement.pdf

Interactive comment on Drink. Water Eng. Sci. Discuss., 5, 351, 2012.

Appendix: figures in page 372 should be replaced by these figures.

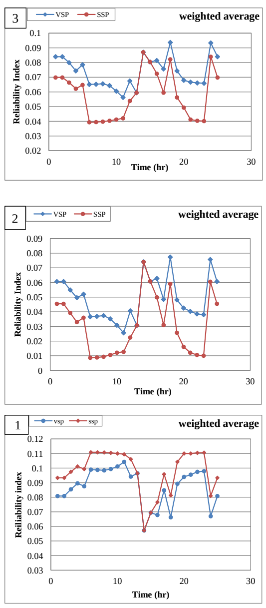

Fig. 1. The comparison of reliability of two type of pumps (VSP, SSP), with weighted average of four scenarios using three nodal pressure equations.