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Reliability of Components in a System under Delta-Star Transformation

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Abstract- In this manuscript, we have to analyze of an independent unit through exact expressions for the conversion of a delta-star network into a star network. In this regards, we have to simplify complex reliability block diagram consisting two or three state devices but the transformation can be carried out under certain conditions according in this state the Delta-star transformation can be quite easily handle network containing more than one bridge configuration. The expressions are interrelated and require less computation time for finding equivalent star configuration. This study also explain the feasibility of converting a star in a dependability network into an equivalent delta under specific circumstances, proving that the likelihood of an element succeeding in an equivalent star equals the likelihood of the corresponding element failing.

Keywords: Reliability Block Diagram, Delta-star Transformation, System Reliability

1. Introduction

Think about the problem of creating an analogous delta (star) from a star (delta) in a reliability network with perfect vertices and imperfect undirected edges. It is believed that such transformations are frequently impossible if the probabilities of the elements of the given star/delta are rational integers. However, here we show that star-delta and delta-star transformations are possible under certain conditions. The probability of an element of an equivalent star (delta) succeeding is also shown to be equal to the probability of the corresponding element of the given delta (star) failing. Gupta, *et al.,* (1978) define to simplify complicated reliability block diagrams for 2-state or 3-state devices, the research presents new exact formulas for delta-star transformation. These formulas can be derived for star-delta transformation, are related, and take less calculation time [1]. Gadani, (1981) define the equations for a delta-star transformation's success/failure and failure rate are presented in his paper, and vice versa. It proposes an iterative method for determining the failure probability in a star-delta transformation by solving three nonlinear algebraic equations. While the star-delta transformation has a respectable level of precision, the delta-star transformation is extremely accurate. Only in cases when the delta-star transformation is impractical during network reduction is it advised [2]. Asgarpoor, et *al.,* (1986) Sharma, *et al.,* (2010 & 2011) discuss a novel method for figuring out the maximum network flow between nodes is put forth, utilizing delta-star or star-delta transformations. This entails shrinking the network until a single arc is achieved and breaking down complicated structures into series parallel configurations. System reliability is then calculated using this single arc's capacity [(3), (4) and, (5)]. Kumar, *et al.,* (2012 & 2015) define a network strategy that takes unreliable nodes into account is presented to determine the frequency and length of outages in large complex networks. Large systems with dependable nodes on contemporary computers can be handled by the accurate approach. The results contain minor mistakes due to the delta-star modifications [6] and, [7]. Rathore, *et al.,* (2017) and, Sharma, *et al.,* (2019 & 2020) analysis that, when sources are present, the source transformation theorem and source shifting technique give relations for transformations from delta to star and star to delta. Compared to mesh or node analysis, these techniques are less complicated. Any delta circuit may be transformed into a unique star circuit using the source transformation theorem, and any star circuit can be transformed into a unique delta circuit using the source shifting technique. When current sources are present, the methods can be expanded to star and delta circuits [(8), (9) and, (10)]. Sharma, *et al.,* (2022) and, Haddi, *et al.,* (2022) show that, the three reduction techniques for determining the dependability of complicated networks is present in his study. The first, referred to as reduction to series elements, entails updating parallel pathways to reduce series detail. When important components fail once and succeed twice, the second technique calculates network reliability using the law of total probability, combining these probabilities to determine system dependability. The third technique, known as the delta-star transformation, simplifies complicated networks [11] and, [12]. Shuai, *et al.,* (2023) and, Arun, *et al.,* (2023) define a motor's speed range is essential to its functioning, and conventional AC motor control techniques set a maximum speed limit for the motor. A star-delta switch, which depends on a mechanical relay and has a dead zone that affects torque output, is suggested as a way to increase the speed range. A DC-bus capacitor is used in this paper's proposed star-delta soft switching technique to supply zero axis current during the transient phase. The effectiveness of this approach is confirmed by experiments, which indicate that it can be more stable than hard switching techniques in motor drives [(13), (14), (15)] Sharma *et al.,* and, Singh *et al.,* (2024) describe a method for examining the architectural design space in the implementation of complex systems that aim to solve issues with formal architecture definition, trade-offs, and selection within the architectural design space [16] and, [17]. Singh *et al.,* (2025) define a unique approach to assessing the structural relevance of a component is proposed and compared with the minimal cut-set method utilizing typical systems (serial, parallel, k out of n, and bridge type) [(18), (19), and (20)]. Parashar *et al.,* (2025) define a functional system's components affect how reliable it is.

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Frequently, higher-order elements are more important. Components can be enhanced, added, or made redundant to increase reliability. According to their importance, the Fussell-Vesely method arranges the components in either ascending or decreasing order [(21), (22), (23)]. Treating probability as a point in a Cartesian frame, this note offers a simple approach to system reliability evaluation. In order to compare the results with classical approaches, formulas are created for series, parallel, series-parallel, and bridge networks.

In Section 2, define the objective of this article. Section 3; discuss the basic concept regarding this research. In Section 4, define the methodology for transform a bridge network to its equivalent parallel and series form. In Section 5, analyze five independent unit bridge network with given unit reliability, and Section 6, conclude that the method is the simplest and a practical method for evaluating reliability unit bridge network and the transform a bridge network to its equivalent parallel and series form.

2. Objective

Our objective of this article is useful to evaluate the reliability of independent units of bridge network and also applied to the theoretical analysis of delta-star transformation, and also demonstrates that the probability of an element in an equivalent star (delta) succeeding is equal to the probability of the corresponding element in the provided delta (star).

3. Basic Preliminaries

3.1 Probability

In the domain of probability, the concepts of failure or malfunction are intimately associated with satisfactory performance. The equipment is either operating well or has failed or malfunctioned when it is in operation because these two occurrences are mutually exclusive. Probability is defined by

$$P(c) = \lim_{n\to\infty}\left(\frac{N}{n}\right)$$

$P(c)$, is the probability that event c will occur in repeated experiments, where it occurs N times. $0 \le P(c) \le 1$ is the reliability of an event, let's say c, occurring.

3.2 Reliability

Reliability is the capacity of a system to operate without failure for a predetermined amount of time under specific operating circumstances and with the least amount of time lost for repairs and preventive maintenance. Reliability is defined as

$$\mathrm{R}(t)=\int_t^{\infty} f(x)dx$$

4. Methodology

The transform a bridge network to its equivalent parallel and series form if a minor error in the end result, but the method is practically solve the purpose to evaluate the nearly and likely network reliability of the system. Once a bridge network is transformed to its equivalent series and parallel form, the network reduction approach can be used for obtaining network reliability. According in this state the Delta-star transformation can be quite easily handle network containing more than one bridge configuration. The expressions are interrelated and require less computation time for finding equivalent star configuration.

Notations

R : Reliability of a General System
R_{ij} : Reliability of the component connected between nodes i & j
R_s : System Reliability
R_j : Unit Reliability for Bridge Network

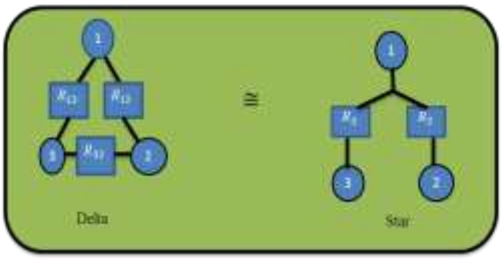
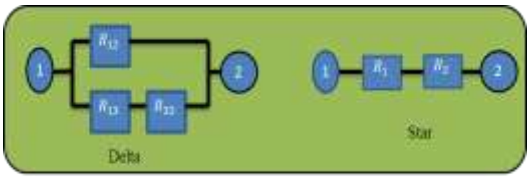
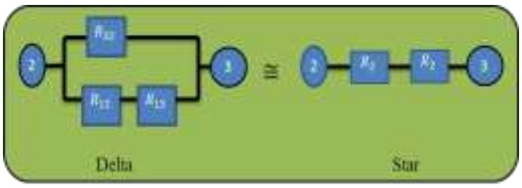


Fig. 1: Delta to Star equivalent reliability Diagram

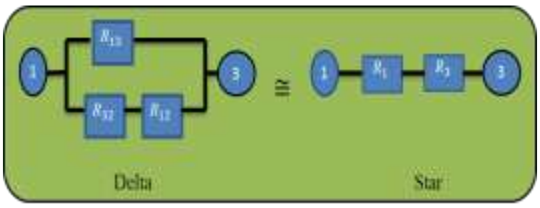
In Fig. (1), the number 1, 2 and 3 denote nodes, the block units and R_1, R_2 & R_3 represent unit reliability. We have to define the Delta-star equivalent relation below as shown in Fig. (2):



Dig. (i)



Dig. (ii)



Dig. (iii)

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Fig. 2: Delta-star equivalent diagram (i), (ii), (iii)

Equating the equations as given below:

$$\left.\begin{aligned} R_1R_2 &\cong 1-(1-R_{12})(1-R_{13}R_{32}) \\ R_3R_2 &\cong 1-(1-R_{32})(1-R_{12}R_{13}) \\ R_1R_3 &\cong 1-(1-R_{13})(1-R_{32}R_{12}) \end{aligned}\right\} \ldots (4.1)$$

By solving Eqn. (4.1), we obtain

$$\left.\begin{aligned} R_1 &= \sqrt{\frac{rt}{s}} \\ R_2 &= \sqrt{\frac{rs}{t}} \\ R_3 &= \sqrt{\frac{st}{r}} \end{aligned}\right\} \ldots (4.2)$$

Where,

$$\left.\begin{aligned} r &\cong 1-(1-R_{12})(1-R_{13}R_{32}) \\ s &\cong 1-(1-R_{32})(1-R_{12}R_{13}) \\ t &\cong 1-(1-R_{13})(1-R_{32}R_{12}) \end{aligned}\right\} \ldots (4.3)$$

5. Results and Numerical Discussion

A five independent unit bridge network with given unit reliability $R_j \forall j = 1,2,3,4,5$ in given Fig. (3) nodes 1, 2 and 3 denote delta configuration and discuss star equivalent units reliability.

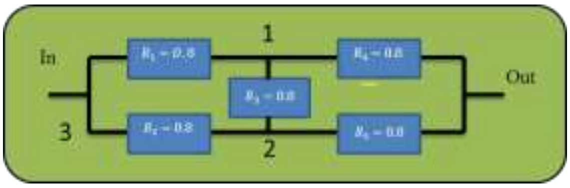
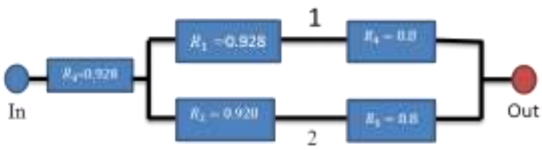


Fig. 3: A five unit bridge network with given unit reliabilities

$$R_1 = \sqrt{\frac{rt}{s}} = 0.928 = R_2 = R_3$$

Where, $r = s = t = 0.928$



We have

$$R_{BridgeNetwork} = R_3\{1-(1-R_1R_4)(1-R_2R_5)\}$$
$$\cong 0.8664$$

A function reduction technique for star-delta transformation and uses failure probability for node pairs to generate delta-star and star-delta transformation equations for a device networks.

6. Conclusion and Future Direction

We conclude that the method is the simplest and a practical method for evaluating reliability unit bridge network and the transform a bridge network to its equivalent parallel and series form. However it is to be noted that the transformation process introduces a minor error in the end result, but it basically means that for practical purpose the Delta-star method is quite effective.

In the future, the main reliability parameters for development engineers will be introduced, together with the mathematics needed for reliability analysis. It determines reliability metrics for electronic systems of failure rates. The failure modes of electronic components, how to compute the necessary parameters for individual components and modules, and how to calculate system reliability from individual component reliability are also better explain in the future work for improving the dependability of electronic systems.

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Author Contribution

C K Sharma organized the original work and review; Rajeev performed the work's simulations, methodology, and data conceptualization.

Conflict of Interest

There are no conflicts of interest regarding the publication of this article.

Ethical Statement

This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. H. Gupta and J. Sharma, "A Delta-Star Transformation Approach for Reliability Evaluation," *IEEE Transactions on Reliability*, vol. R-27, no. 3, pp. 212–214, Aug. 1978, doi: https://doi.org/10.1109/tr.1978.5220328.
2. J. P. Gadani, "System Effectiveness Evaluation Using Star and Delta Transformations," *IEEE Transactions on Reliability*, vol. R-30, no. 1, pp. 43–47, Apr. 1981, doi: https://doi.org/10.1109/tr.1981.5220959.
3. C. Singh and S. Asgarpoor, "Reliability Evaluation of Flow Networks Using Delta-Star Transformations," *IEEE Transactions on Reliability*, vol. 35, no. 4, pp. 472–477, 1986, doi: https://doi.org/10.1109/tr.1986.4335510.
4. C. K. Sharma, M. M. Gupta, and A. Kumar, "Reliability analysis with analytical discussion of the system with correlated failures," *International Research Journal of Management Science and Technology*, vol. 1, no. 3, pp. 104–115, Oct. 2010.
5. A. Kumar, M. M. Gupta, and C. K. Sharma, "Reliability measurement for the exponential case of chance failures discuss with data analysis," *International Research Journal of Management Science and Technology*, vol. 2, no. 3, pp. 212–218, Nov. 2011.
6. C. K. Sharma, "Cost analysis of 2-units electronic parallel redundant system for three states,"

International Research journal of Management Sociology & Humanities, vol. 3, no. 1, pp. 290–296, Jan. 2012.

7. V. Tyagi, B. S. Kalra, C. K. Sharma, and A. Kumar, "Cost Benefit Analysis of a Two Unit Parallel System with Response Period of Repair Facility," *Multidisciplinary Scientific Reviewer*, vol. 2, no. 5, pp. 39–45, Nov. 2015.
8. T. S. Rathore and J. L. Rathore, "Star ↔ Delta Transformation in the Presence of Sources," *IETE Journal of Education*, vol. 58, no. 2, pp. 67–77, Jul. 2017, doi: https://doi.org/10.1080/09747338.2017.1384331.
9. C. K. Sharma, "Discuss the Unreliability of a Component through Simple Three Phased Model System," *Journal of Pure & Applied Science & Technology*, vol. 9, no. 1, pp. 1–8, Jan. 2019.
10. C. Kumar Sharma, "Redundancy Optimization of a System under the Fault-tolerant System," *Journal of Pure & Applied Science & Technology*, vol. 10, no. 1, pp. 1–5, Jan. 2020.
11. Fouad and A. Haddi, "Using some reducing techniques to simplify reliability network," *AIP conference proceedings*, vol. 2398, pp. 060019–060019, Jan. 2022, doi: https://doi.org/10.1063/5.0093437.
12. M. H, K. Lochan Behera, C. K. Sharma, and S. Gupta, "Leadership and Quality of Life: Navigating Health Systems Through Crisis Management and Beyond of Life in Chronic Disease Management," *Health Leadership and Quality of Life*, vol. 1, no. 1, p. 147, Dec. 2022, doi: https://doi.org/10.56294/hl2022147.
13. S. Dey, C. K. Sharma, and P. Varma, "The Role of Data Analytics in Enhancing Decision-Making Processes in Healthcare Management," *Health Leadership and Quality of Life*, vol. 1, no. 1, Dec. 2022, doi: https://doi.org/10.56294/hl2022.93.
14. Yixuan Shuai, D. Jiang, Z. Chen, Z. Liu, H. Sun, and P. Li, "Study of Star-Delta Soft Switch to Extend AC Motor High Speed Operation Region," *CES transactions on electrical machines and systems*, vol. 7, no. 3, pp. 248–255, Sep. 2023, doi: https://doi.org/10.30941/cestems.2023.00049.
15. G. Arun, S. K. Garud, P. Varma, and C. K. Sharma, "Analysing the Effects of Environmental Changes on Public Health Quality Indicators," *Health Leadership and Quality of Life*, vol. 2, no. 2, pp. 243–243, Dec. 2023, doi: https://doi.org/10.56294/hl2023243.
16. N. Singh, Nitin Kasana, and Chetan Kumar Sharma, "Analysis of the constant failure density of a component and its reliability," *CRC Press eBooks*, vol. 1, no. 1, pp. 291–294, Aug. 2024, doi: https://doi.org/10.1201/9781003534136-46.
17. Chetan Kumar Sharma, M. Zuhaib, Nitin Kasana, and N. Singh, "Discussion For Economic Agriculture Through Mathematical Programming," *IIP Publications*, vol. 3, no. 1, pp. 129–138, Feb. 2024, doi: https://doi.org/10.58532/v3bcag16p2ch3.
18. C. K. Sharma *et al.*, "The Role of Technology in Transforming Healthcare Education," *Health Leadership and Quality of Life*, vol. 3, no. 3, Dec. 2024, doi: https://doi.org/10.56294/hl2024.385.
19. Nitin Kasana, N. Singh, and C. K. Sharma, "Reliability analysis of the replacement of equipment in average annual cost," *AIP conference proceedings*, vol. 3262, no. 1, pp. 020011–020011, Jan. 2025, doi: https://doi.org/10.1063/5.0247977.
20. C. K. Sharma, N. Singh, and N. Kasana, "Reliability Analysis of Random Component Failure in a Series Hydraulic Robot Configuration," *2025 3rd International Conference on Disruptive Technologies (ICDT)*, pp. 368–372, Mar. 2025, doi: https://doi.org/10.1109/icdt63985.2025.10986701.
21. V. V. Verma, Y. P. Reddy, A. Tomar, C. K. Sharma, and V. K. Sharma, "Computational Approaches Based Evolutionary Analysis to Identify the Genetic Variation Among Kelch 13 Gene Linked to Artemisinin Resistance in Plasmodium Falciparum," *2025 International Conference on Cognitive Computing in Engineering, Communications, Sciences and Biomedical Health Informatics (IC3ECSBHI)*, pp. 1104–1108, Jan. 2025, doi: https://doi.org/10.1109/ic3ecsbhi63591.2025.10991235.
22. N. Singh, N. Kasana, and C. K. Sharma, "Analysis of Reliability Allocation for a Component in Standby Redundancy System," *2025 International Conference on Cognitive Computing in Engineering, Communications, Sciences and Biomedical Health Informatics (IC3ECSBHI)*, pp. 1122–1127, Jan. 2025, doi: https://doi.org/10.1109/ic3ecsbhi63591.2025.10990981.
23. R. Parashar, A. Chauhan, and C. K. Sharma, "Analysis of Component Reliability Through Fussellvesely Measurement," *2025 International Conference on Cognitive Computing in Engineering, Communications, Sciences and Biomedical Health Informatics (IC3ECSBHI)*, pp. 352–356, Jan. 2025, doi: https://doi.org/10.1109/ic3ecsbhi63591.2025.10991208